BEMO-COFRA

Brazil-Europe Monitoring and Control Framework

(Project No. 288133)

D2.2 Initial Requirements Report

Published by the BEMO-COFRA Consortium

Dissemination Level: Public

European Commission
Information Society and Media

CNPq
Conselho Nacional de Desenvolvimento Científico e Tecnológico

SEVENTH FRAMEWORK PROGRAMME

Project co-funded by the European Commission within the 7th Framework Programme
and
Conselho Nacional de Desenvolvimento Científico e Tecnológico
Objective ICT-2011-EU-Brazil

Document version: 1.0 Submission date: Date

Document control page

Document file: D2.2 Initial Requirements Report_v1.0
Document version: 1.0
Document owner: Juliana Nogueira Vilela (COMAU)

Work package: WP2 – Requirements Engineering and Validation
Task: T2.2 – Manufacturing scenario and requirements specification
Deliverable type: R

Document status: ☐ approved by the document owner for internal review
☐ approved for submission to the EC

Document history:

Version	Author(s)	Date	Summary of Changes made
0.1	Trine F. Sørensen	2012-01-12	Table of contents
0.2	Juliana Vilela	2012-01-25	First content, ch. 2,4 and 6
0.3	Trine F. Sørensen	2012-01-31	Methodology chapter added
0.4	Juliana Vilela, Trine F. Sørensen	2012-01-31	Executive Summary, Conclusion and Requirements added
1.0	Juliana Vilela	2012-01-31	Final version submitted to the European Commission

Internal review history:

Reviewed by	Date	Summary of comments
Name of reviewer 1	2011-09-01	
Name of reviewer 2		

Index:

1. Executive summary

The BEMO-COFRA project aims to develop an innovative distributed framework which allows networked monitoring and control of large-scale complex systems by integrating heterogeneous smart objects, legacy devices and sub-systems, cooperating to support holistic management and to achieve overall system efficiency with respect to energy and raw materials.

The purpose of this deliverable is to give a systematic formalization of an initial set of scenarios, relevant stakeholder requirements and sub-system requirements. The scenarios were the base to elicit the requirements and these requirements will guide the developments in the common source of user requirements for the BEMO-COFRA consortium.

Using scenarios is a powerful approach to keeping a human-centred focus throughout the application specification process, and to allow early user involvement. A scenario is an acknowledged way of communicating the vision of a particular system, as well as to explain and document requirements. Creating scenarios of end user behaviour and interaction with platform functionality is an extremely useful instrument for identifying key technological, security, socioeconomic and business drivers for future end user requirements. The scenarios provide a vision framework for the subsequent iterative requirement engineering phase.

The User Scenarios have been developed following a 2-day User Scenario and Requirement workshop in Recife, Brazil, and a follow-up workshop in Bonn, Germany. The user workshops were focused on context of use, benefits of support by the future BEMO-COFRA platform, and user requirements.

This deliverable presents two user scenarios: a Brazilian User scenario and a European User Scenario. Only the Brazilian User Scenario will be implemented and user requirements will thus been elicited from only this scenario. This scenario is set in the context of the body welding and assembly line of a car manufacturer. It focuses on three areas or themes: 1) Layout and configuration, 2) Operational monitoring and maintenance, and 3) Consumption measurements.

Requirements will be documented using the Volere Scheme as this has proved an easy and useful tool for creating and tracking requirements. In BEMO-COFRA, we define 3 overall groups of requirements and subsystem functionality:

- Functional requirements: What is required from different user perspectives?
- Business requirements: What is required to live up to business needs and how will current business practices be supported?
- Efficiency requirements: What is required in terms of energy and raw material efficiency improvements (which include the formulation of a set of business policies)?

As the BEMO-COFRA project has adopted an evolutionary requirement engineering, specification and design methodology, there will be two iteration cycles during the project's lifetime. The iterative approach allows us to refine and update requirements based on user evaluation and validation. The present deliverable thus represent the, as its title suggests, initial requirements and a first official (although internal) update will be presented in the internal working document WD2.2 Updated requirements report planned for release in M7.

2. Introduction

2.1 Purpose, context and scope of this deliverable

The purpose of this deliverable is to present the User Scenarios and its relevant stakeholders. From the User Scenario an initial list of user requirements and sub-system requirements will be elicited. These requirements will guide the developments in the common source of user requirements for the BEMO-COFRA consortium. The scenarios and the list of requirements in this document reflect the work performed in task T2.2 Manufacturing Scenario and Requirements Specification. The Brazilian scenarios and requirements were emerged from one workshop conducted with representatives from the car manufacturing domain and partners of BEMO-COFRA project. European scenarios and requirements were reused from the ebbits project, which one of the domains is the manufacturing domain as the BEMO-COFRA project.

This deliverable is organized as follows:

- Chapter 3 describes the methods and principles applied for the user-centred development of software in general;
- Chapter 4 describes the Brazilian and European user scenarios for BEMO-COFRA project in a visionary future of 5 years;
- Chapter 5 lists the initial set of functional, non-functional, efficiency and business requirements for BEMO-COFRA platform in Brazil and reuse the ebbits requirements for BEMO-COFRA platform in Europe;
- Chapter 6 provides a conclusion focus on the next steps.
- Appendix A illustrates the complete initial requirements in a table that follows the Volere template.

2.2 Background

The BEMO-COFRA project aims to develop an innovative distributed framework which allows networked monitoring and control of large-scale complex systems by integrating heterogeneous smart objects, legacy devices and sub-systems, cooperating to support holistic management and to achieve overall system efficiency with respect to energy and raw materials.

The BEMO-COFRA features a Service oriented Architecture (SoA) and a middleware able to expose smart objects, legacy devices and sub-systems' capabilities by means of web services thus supporting syntactic and semantic interoperability among different technologies coexisting in the overall monitoring and control framework. Wireless Sensor and Actuator Network (WSAN) devices, legacy sub-systems and devices will thus be able to interact and cooperate, orchestrated by a manager in charge of enforcing a distributed logic with the overall monitoring and control network.

BEMO-COFRA reuses the results of the well-reputed Hydra IP and Pobicos STREP and the recently started ebbits IP featuring a Service Oriented Architecture (SOA) and a middleware able to expose smart objects, legacy devices and sub-systems' capabilities by means of web services. Syntactic and semantic interoperability among coexisting technologies in the overall monitoring and control framework is made available.

The integration of heterogeneous smart objects, legacy devices and sub-systems will achieve overall systems' efficiency with respect to energy and raw materials and support holistic management. The BEMO-COFRA project will address both technological aspects and user needs to promote a wider adoption of large-scale networked monitoring and control solutions.

3. User Centred Design Procedure

An essential property of the User Centred Design approach is that it has to be adapted to the specific requirements of the respective project. Requirements are descriptions of how the system should behave, application domain information, constraints on the system's operation, or specifications of a system's property or attribute. This chapter gives an overview on how the standard procedure has been instantiated and adapted to the BEMO-COFRA project.

3.1 User Centred Design Methodology

User centred design is a project approach that puts the stakeholders of a product or a system at the centre of its design and development. User centred design seeks to answer questions about users and their tasks and goals, such as "who are the users of this product/system/service?", "what are user tasks and goals?", "what functions do users need from this product/system/service?". The answers to these questions are then used to drive development and design. That is done by involving and talking directly to key stakeholders during the course of the project, starting from its very beginning, in order to assure that the product/system/service will deliver the foreseen requirements.

The standard ISO 9241-210 "Ergonomics of human-system interaction -- Part 210: Human-centred design for interactive systems" (ISO 9241-210:2010) which is a part of the multi-part standard ISO 9241 and a revision of the withdrawn ISO 13407 "Human-centred design processes for interactive systems" (ISO13407:1999), outlines four essential activities in a user-centred design project:

1. Requirements gathering - Understanding and specifying the context of use
2. Requirements specification - Specifying the user requirements
3. Design - Producing design solutions
4. Evaluation - Carrying out user-based assessment of the product or system.

The first two phases consist of the collection of requirements through end-user involvement in workshops and interviews. In these phases one of the core tasks is to negotiate and facilitate the communication across the well-known user-developer gap while acknowledging the different forms of expression and different requirements on each side.

The user-centred design process reflects an iterative process with no sharp start and end points: eliciting the 'context of use' requires intensive user involvement continuously for the whole duration of the process, and the requirements elicitation likewise extends well into the design proposal phase. There are four essential human-centred activities recommended by the ISO standard (ISO-9241-210):

1. to understand and specify the context of use
2. to specify the organizational and user requirements
3. to produce design solutions
4. to evaluate design regarding requirements

The human-centred design approach implies an iterative life cycle in a project. Iterative cycles allow advancing from specification to implemented prototypes, from experience and evaluation to improved specifications and improved prototypes. A system is perceived as a socio-technical system, i.e. the novel technology is a fit between a technical system and its usage (Emery &Trist., 1960). The design proposals are based on the current understanding of the context of use. These proposals provide an idea on how to meet identified or assumed requirements. The evaluations of the design proposals yield a richer understanding of the context of use and new or modified requirements and thus guide the evolutionary improvement of the design.

3.2 The Adopted Approach in BEMO-COFRA

BEMO-COFRA has adopted evolutionary requirement engineering, specification and design methodology, which complies with the following broad template for each iteration:

- User requirements engineering and refinement
- Architecture design specification and refinement
- Enabling technologies research to implement architecture
- Prototype development, system integration and testing
- Conformance testing, usability validation
- Lessons Learned and change analysis.

The specific methodologies that have been used include evolutionary design and refinement re-engineering. Lessons learned as the project progress, will be used to adjust initial requirements incorporating emergent requirements. The project partners will be continuously informed of the requirement engineering process in order to enable the necessary and timely modification of design specifications and possible re-engineering of affected modules.

The methodology calls for comprehensive iterative requirements and stakeholder analysis based on initial requirements gathered from scenario thinking. These requirements would encompass the needs and priorities of the users, as well as the business and efficiency requirements. In order to begin to elicit these initial user requirements, a comprehensive user scenario has therefore been developed in close cooperation with the user, Comau Brasil (Chapter 4).

3.2.1 User Scenarios

A scenario is an acknowledged way of communicating the vision of a particular system, as well as to explain and document requirements. Creating scenarios of end user behaviour and interaction with platform functionality is an extremely useful instrument for identifying key technological, security, socioeconomic and business drivers for future end user requirements. The scenarios provide a vision framework for the subsequent iterative requirement engineering phase.

Scenarios are part of the system specification; they explicitly deal with the usage of a technical system, the context of use, and the allocation of function between the technical system and human users. Later, when a prototype is available, end users can try it and gain personal experience with the system. Iterative cycles allow advancing from specification to implemented prototypes, from experience and evaluation to improved specifications and improved prototypes.

In BEMO-COFRA the user scenario in Chapter 4.1 was developed in close cooperation with the user, Comau Brazil, and the other project partners. A scenario for the European case is also presented in this deliverable (Chapter 4.2) but it is important to note here that only the Brazilian scenario will be implemented in BEMO-COFRA. Thus when discussing user requirements we are concerned with the Brazilian case only unless otherwise explicitly noted.

From the scenario a systematic formalisation of all relevant user requirements and subsystems requirements will be derived. This process has started already and will be continuously updated.

3.2.2 User Workshops

A 2-day User Scenario and Requirement workshop in Recife (5-6 December 2011) was organised in order to discuss the state of play and visions for BEMO-COFRA with the users. The workshop was useful because it allowed users and developers to discuss ideas and questions and to come to a common understanding of the visions for the BEMO-COFRA platform that will be installed and validated at the user site in Belo Horizonte, Brazil. During the workshop the basic outline of the user scenario was defined which was then later been refined and validated by Comau.

As a part of this refinement process, a workshop in Bonn (26 January 2012) was organised at FIT in Bonn, Germany between FIT, INJET and ISMB. COMAU participated via Skype. This workshop allowed partners to clarify outstanding issues and questions in relation to the scenario, stakeholders and the requirements elicitation process and definition. The results from this workshop will be used to elicit the initial technical requirements which will feed into the first cycle.

The resulting user scenario is presented in this deliverable in Chapter 4.1.

3.3 Derivation of Initial Requirements

The procedure for the initial requirement elicitation has been selected according to the overall philosophy of the iterative requirement engineering which foresees an engineering process of initial requirements and an iteration cycle to be performed after the first year in the project. The specific methodology includes evolutionary design and refinement engineering. Furthermore, the evolutionary design allows requirement refinement to obtain an accurate match with the real needs of each stakeholder.

The aim of this procedure has been the achievement of a systematic formalisation of all relevant stakeholder initial requirements and the initial requirements for the BEMO-COFRA platform, mainly based on the outcomes of a 2-day User Scenario and Requirement workshop in Recife (5-6 December 2011) and a workshop in Bonn (26 January 2012) to refine the scenario and discuss requirements (see above). Input to the scenarios and this initial requirement elicitation phase also came from the general project, technical meetings and the deliverable D2.1 State of Play in the Production Monitoring and Control Systems.

In BEMO-COFRA, we define 3 overall groups of requirements and subsystem functionality:

- Functional requirements: What is required from different user perspectives?
- Business requirements: What is required to live up to business needs and how will current business practices be supported?
- Efficiency requirements: What is required in terms of energy and raw material efficiency improvements (which include the formulation of a set of business policies)?

Functional requirements give the specification of the product's functionality, derived from the fundamental purpose of the product, whereas non-functional requirements are the properties of the product, the qualities and characteristics that make the product attractive, usable, fast or reliable.

Non-functional requirements can be grouped according to following subcategories:

- Look and feel requirements (intended appearance for end users)
- Usability requirements (based on the intended end users)
- Performance requirements (how fast, big, accurate, safe, reliable...)
- Operational requirements (what is the intended operating environment?)
- Maintainability and portability requirements (how changeable it must be)
- Security requirements (security, confidentiality and integrity)
- Cultural and political requirements (human factors)
- Legal requirements (conformance to applicable laws)

Of course look and feel, usability and cultural requirements are of only secondary relevance for the assessment of requirements for a software platform, but are nevertheless important for the assessment of qualities and aspects of the user interfaces to be developed.

3.4 Description and Organization of Requirements

The workflow to ensure that all necessary details and procedures in the Volere Schema are adhered is complex enough so that we decided to support this process with the use of a tool for all partners within the project. Based on different partners' experiences with different tools, it was decided that JIRA is the most suitable tool. JIRA is a web based bug tracker that allows implementing and tracking the workflow of the Volere schema. All partners in BEMO-COFRA have been given access to

JIRA with a unique username and password so that they can create requirements. Figure 1 shows the screenshot of JIRA that appears when selecting "Create a new requirement":

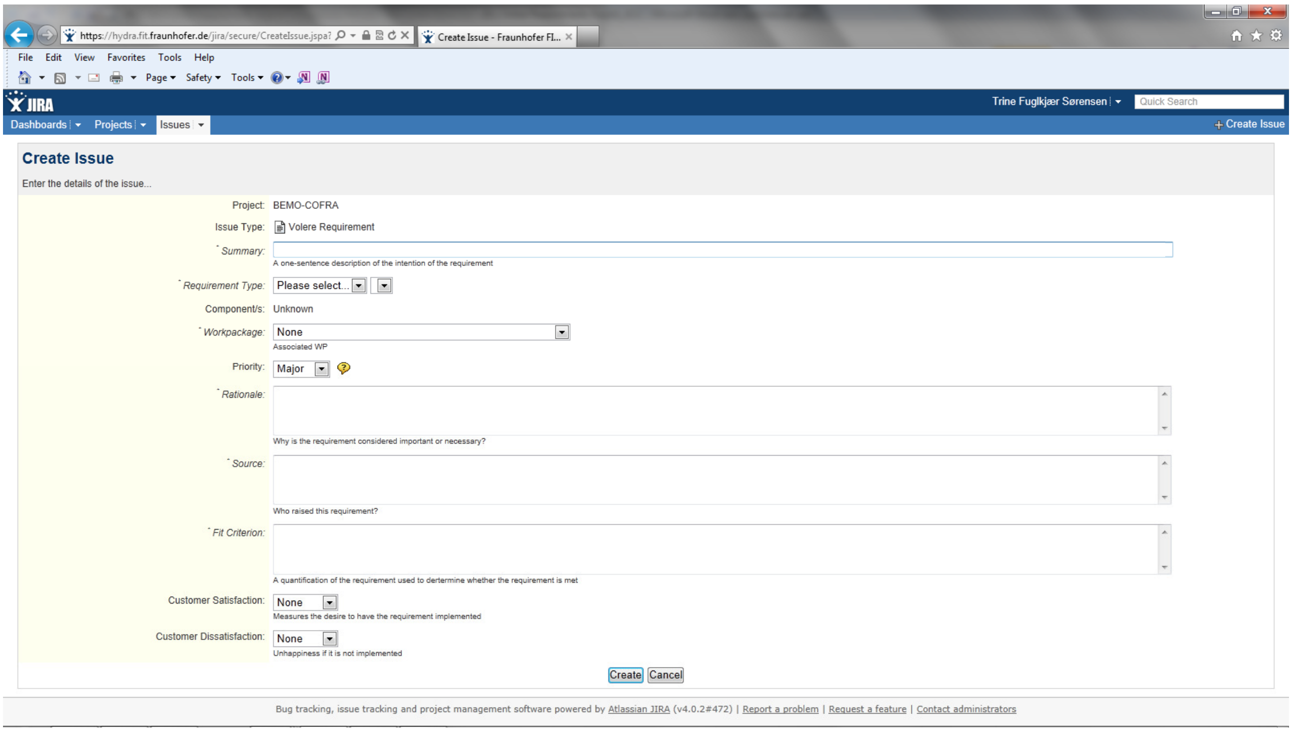

Figure 1: Screenshot of JIRA when creating a new issue (requirement).

The requirements are entered to JIRA. JIRA ensures that always two persons control the quality of the requirements. One person (the "Reporter") enters the requirement to JIRA, whereas another person controls ("the Assignee") and passes the requirement through the quality gateway. You can see the roles of "Reporter" and "Assignee" in the screenshot of Figure 2 below. Each requirement tough has a reference to the work package it relates to and to the component of the middleware or the respective quality or attribute of a component that it describes. It is obvious that this helps structuring the requirements.

The requirements are also prioritised. Priority is a very important field that defines the relevance of this requirement in relation to the other requirements. It allows classification of the specified requirement in five categories: "Blocker", "Critical", "Major", "Minor", and "Trivial". The rating must be carefully assigned and is the last step of the requirement specification before it passes the quality check. The *priority* of a requirement is based on several important aspects included in the Volere schema:

- *The source defining if this requirement was raised by primary or secondary stakeholders [the latter less important], or by discussion within the consortium, by vision and technical scenarios or the DOW.*
- *The assessment of customer satisfaction and dissatisfaction if this requirement is achieved respectively missed.*
- *The estimation if the requirement is within the scope of the project.*
- *The component that the requirement is associated to.*

Figure 2 below shows a screenshot of JIRA with one open requirement:

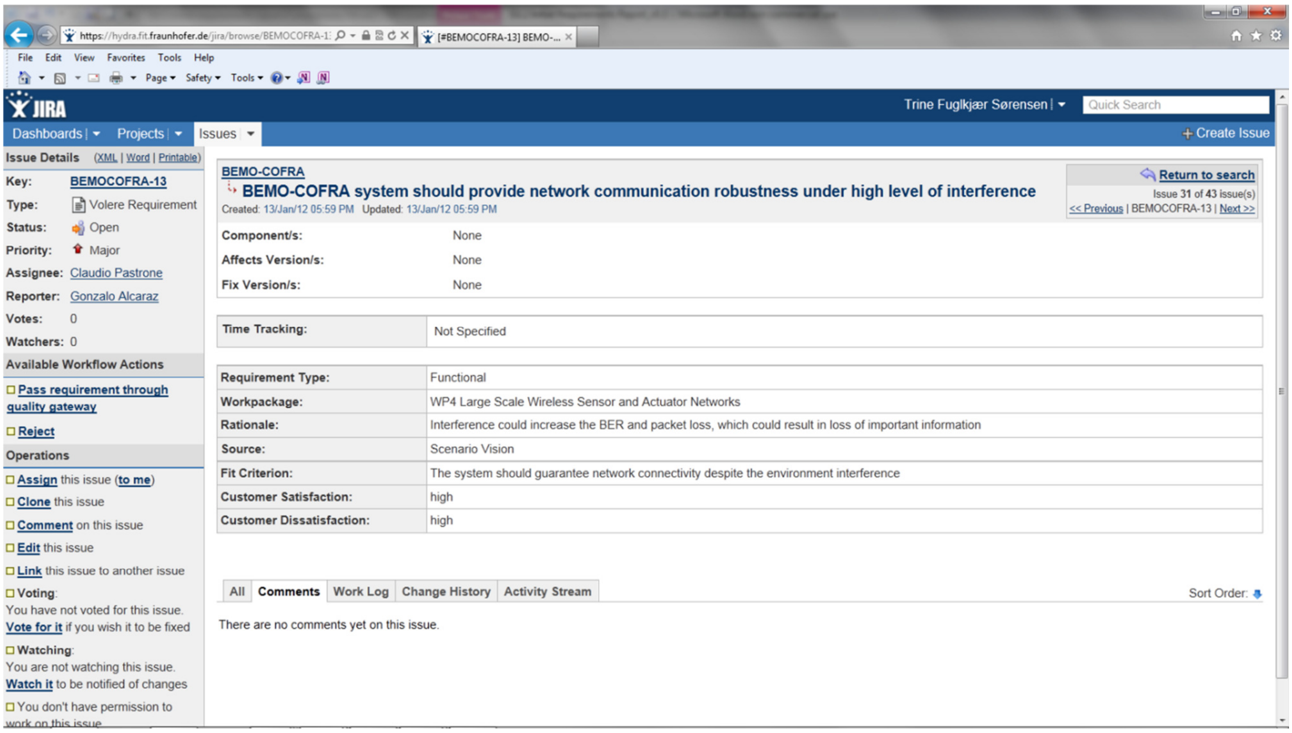

Figure 2: Screenshot of JIRA with one requirement.

The summary of a requirement contains a one-sentence description of the requirement. The description is the intent of the requirement and should be clear and brief.

The rationale of a requirement expresses the reason behind the requirement's existence. The rationale provides the reason why the requirement is important and the contribution it makes to the product's purpose. The rationale contributes to the understanding of the requirement.

The Fit Criteria is the most important field. Fit criteria are the quantified goals that the solution (i.e. the realization of the requirement) has to meet. This field describes how to determine if the requirement is met. It should be written in a precise quantified manner. The fit criterion sets the standards to which the developer constructs the product.

In order to express dependencies and conflicts among requirements, JIRA allows the definition of links between two requirements by choosing the demand "Link this issue to another issue" under the menu "Operations" (see Figure 2, left hand side of the screen). In addition, the links between two requirements can be named specifying then nature of the link.

It is also possible to edit requirements and add comments (by choosing "Edit issue" in the left hand menu). Figure 3 demonstrates the edit mode in JIRA:

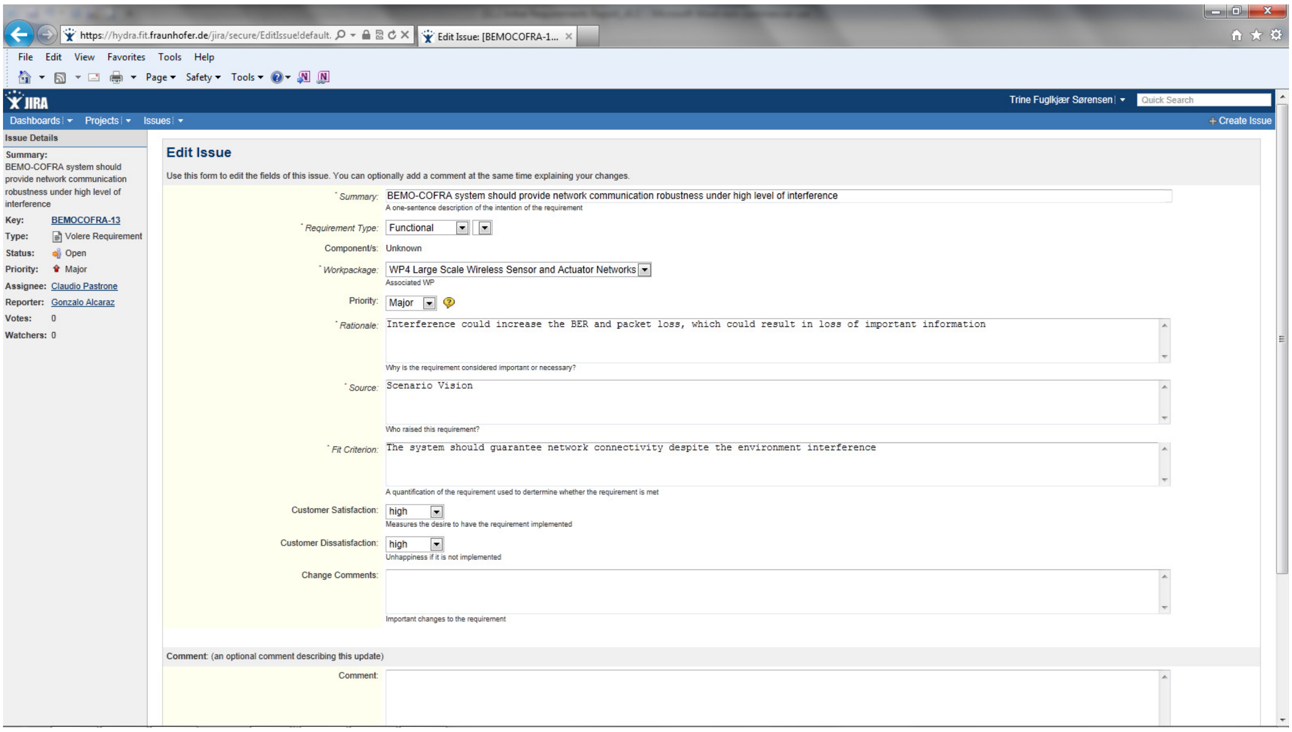

Figure 3: Screenshot of JIRA with a requirement in the edit mode.

3.5 Requirements Analysis and Refinement Phase

Once all requirements have been shaped according to the Volere schema and collected in a common database, a phase of requirements analysis has to be performed. In this phase, a quality control is performed for all requirements. Involved people/partners have the possibility to decide which requirement will become part of the final set and which has to be revised. In this latter case, a feedback to the reporter of the requirement is provided. The quality control is performed by processing requirements along the steps of a workflow which is the schema representing the movements (or transitions) of a requirement through various statuses during its lifecycle.

The foreseen requirement workflow is structured in the following way. When a requirement is inserted in the common database for the first time, its associated status is "open". If it is complete and unambiguous and all its fields are properly filled with the right values, then it passes the quality check, otherwise it fails. There are several reasons for failing to pass the quality check: incompleteness, ambiguity, some fields filled with meaningless values, loss of sense. If the requirement fails the quality check the reasons are sent to the reporter who can correct and update it and re-pass it through the quality check. If the check fails again the same procedure described above is repeated. Eventually all requirements will pass the quality check. That means that they are complete and all fields are filled with proper values. Requirements that have passed the quality check can no longer be edited.

The last step of requirement refinement involves deciding whether a requirement becomes part of the specification or not. A requirement may not be part of the specification if it is a duplicate, or out of scope of the project. When a requirement has been labelled as "part of specification", "duplicate", or "rejected"), its status is "resolved".

Below is a picture of the proposed requirements workflow:

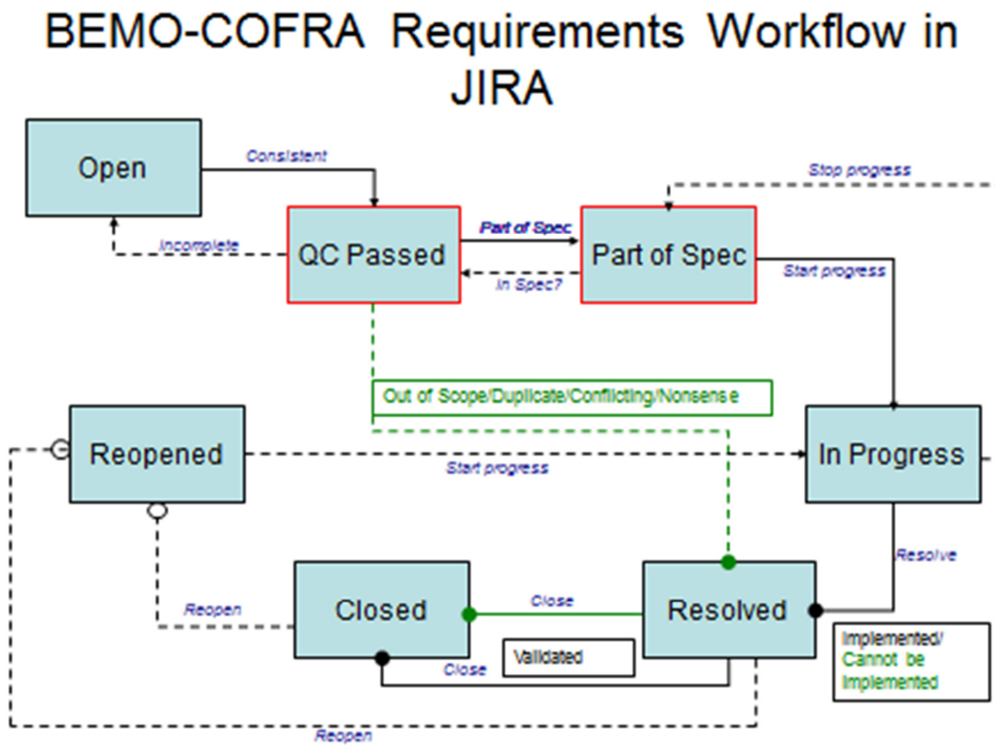

Figure 4: Requirements Workflow

Explanation:

Light blue boxes are Statuses.

Red-line boxes are additional Statuses compared to the JIRA default workflow.

White Text boxes contain possible Resolutions.

Solid arrows show typical workflows.

Dashed arrows indicate less typical workflows.

Green arrows/texts indicate unchanged Resolutions.

Transitions are shown in dark blue italics.

4. BEMO-COFRA User Scenarios

This chapter presents two unique User Scenarios for the BEMO-COFRA user partner COMAU: 1) a Brazilian User Scenario which is the one that will be implemented and validated at COMAU in Belo Horizonte, Brazil and 2) a European User Scenario which have been borrowed from the ebbits project and representing COMAU in Torino, Italy.

For the Brazilian User Scenario, the following relevant stakeholders have been defined:

- Manufacturing plant director: responsible for whole manufacturing industry
- Manufacturing plant manager: responsible for one department
- Technology/Engineering manager: responsible for the technology/engineering used on the production lines (improvements on the manufacturing line, changes on the layout, devices, etc.)
- Line manager: responsible for the correct running of a specific car model line /car model family.
- Production manager: responsible for follow the production of a specific car model line trying to achieve the goal
- Machine operators: people who operates the devices and machines in a production line
- Maintenance crew: people responsible for the maintenance of the devices and machines in the production line. They work on the machines on schedule period or when a problem occurs.
- Machine/devices developers/suppliers: responsible for developing improved machines and devices for the manufacturing lines.

4.1 Brazilian User Scenario

The Brazilian user scenario was made thinking on a horizon of 5 years for the body welding and assembly line in a car manufacturing industry with the BEMO-COFRA platform implemented. The framing station was considered as the main station of the production line.

Introduction

The car manufacturing industry has to continuously adapt to market dynamics; the market is constantly changing and customers are becoming more and more demanding. The manufacturing plants must therefore be flexible and able to quickly adapt to market changes and demands.

In recent years, a greater demand for new cars has meant that the production of cars has increased significantly. In addition, new car models are offered for sale only in short period of time. During this period the production of car can increase 100% in order to meet market demands.

A production line is composed of several production stations. Each station is composed by several devices, such as robots, manual machine guns, automated machine guns, control units, plc, sensors, geometry groups, motors, conveyors, tables (e.g. roller table, turn table), vision systems, elevators, etc.

The changing market demands, and hence the change in production volume, in turn has a great effect on the layout of the production line. It must be very flexible to meet demands e.g. by adding new devices such as sensors, machines and robots. This requires seamless communication internally between sensors and production station plc and between plc's for the stations in order to minimize the time for production layout changes.

Scenario 1: Layout and reconfiguration

Stakeholders: Manufacturing plant director - Manufacturing plant manager - Technology/Engineering manager – Line manager – Production manager – Machine operators

The flexibility of the production lines is closely related to the network infrastructure. Five years ago, cables and connectors made layout changes or installation of new devices quite complex and time consuming. But today, the cable network has been replaced by wireless communication modules. These modules have been thoroughly tested before they were implemented to ensure that they are completely reliable, especially considering the harsh environment in a car manufacturing plant.

Ronaldo, the Technology/Engineering Manager, has worked intensively to redesign the layout to accommodate for increase in production. It is a very complex task, but at least he knows that the recent implementation of the BEMO-COFRA framework has greatly improved the overall flexibility of the line, facilitated implementation of new layouts, and allowed many systems to be reconfigured automatically.

New layouts require robots to be moved to new areas and the sequence of the stations to be reordered. This is now possible without changing the network topology so that an entire production station can be moved to a new location without having to worry about connectivity. Moreover, as stations are wireless, they can be reconfigured automatically, so that any change in production volume can easily be achieved. Reconfiguration of a station involves replacing one station with another, improving the station's performance, changing the connectivity of various devices, improving the cycle time, improving the quality of the process, etc.

The BEMO-COFRA seamless connectivity framework allows Ronaldo to add new devices, subsystems and robots to the unit. Some sensors are just a part of the same layout, while other sensors are completely new to the network, such as ad-hoc consumption sensors and sensors that can improve the production cycle time. These sensors need to be discovered and configured.

Hence, with BEMO-COFRA Ronaldo can now focus on implementing the physical layout and the safety aspects. Safety issues are extremely important and a research group is therefore currently working on programming a new safety framework based on BEMO-COFRA providing laser-based passing sensors with wireless connectivity. Once the lay-out is in place, the production line is instantly up and running again.

Scenario 2: Operational monitoring and maintenance

Line manager – Production manager – Machine operators – Maintenance crew – Machine/device developers

The "BEMMO" car model is in great demand these days and the production is therefore at its peak. Jefferson, who is the BEMMO Line manager, is feeling the pressure because as production rate increases so does the risk of errors, breakdowns and quality problems. He is therefore focusing intensely on being on the forefront and is constantly observing and analysing data from the production stations. The new BEMO-COFRA enabled monitoring system has made it possible to constantly monitor the productivity. Jefferson has had the new monitoring system configured with some predefined parameters for each machine in the production line. Jefferson can easily choose whether he wants to access data for a specific machine, for several machines, for the entire station or the entire line.

The high demands on the production output also put extra pressure on the maintenance crew. They will have to resolve any issue as quickly as possible to avoid serious delays to the production line. With the capacity to produce 60 cars pr. hour, every minute counts and the production line is running at maximum capacity. Recently, maintenance has thus put more focus on proactive action and predictive maintenance. The BEMO-COFRA framework has drastically changed the way the production line is monitored and controlled.

The harsh environment affects not only the wireless communication reliability; it reduces the machines' lifetime as well. So the wireless modules have integrated a system, which monitors all the important machine parameters and sends a message to the maintenance staff, when a machine needs a preventive maintenance intervention. By acting before the failure happens, the machines' lifetime is improved and the downtime of the production line is reduced.

Instead of a simple sound and light alarm at the station when a problem occurs, the maintenance crew now receives more detailed information as to where exactly within the station the problem has occurred. This way the maintenance crew can go straight to the station, already knowing what kind of problem they are going to encounter. For more complex problems, the maintenance crew can use their mobile device to forward the problem with data and pictures to a remote specialist, who can analyse the problem and guide the crew on the floor on how to get the problem fixed.

The monitoring is accomplished by using existing sensors and control applications (e.g. stoppage, slow speed, etc.) or new, ad-hoc sensors and applications (e.g. differential speed, noise, etc.). Also the robot can send detailed performance information to the plc, which controls line or to a backend maintenance system.

With the implementation of the wireless modules, the communication between the station, sensors, plc's and backend systems has an uptime of 99.9% (corresponds to 1 minute / day of failure) is reliable and monitored through a network application. The application shows the performance of the wireless modules and errors are detected and automatically displayed to the maintenance staff.

Scenario 3: Consumption measurements

Manufacturing plant director - Manufacturing plant manager - Technology/Engineering manager – Line manager – Maintenance crew – Machine/device developers

An important point, which is monitored by the BEMO-COFRA framework, is the consumption of supplies such as water, electrical energy, compressed air, lubricants, etc. The increasing consumption of supplies in the last years has incited the Government to adopt a new law that makes it possibly to penalize industries if their consumption exceeds a relative fixed limit. At the same time, the overall unit price for energy consumption has increased as well. In response to global supplies consumption concerns, an intelligent system analysing supplies consumption has been installed.

This system focuses on energy consumption and generates energy consumption reports for each station. It can also generate a detailed energy consumption report for each specific part or device within the station per day shift or couple of hours. These reports give details of selected values e.g. power consumption, water, temperatures, and possible performance parameters of the devices for preventive maintenance purposes.

When a problem in the production arises, the system informs the relevant stakeholder and the presentation of the report is adjusted to each stakeholder's need.

Normal consumption levels are delivered on a weekly basis to the line manager / product designer allowing them to analyse the possibility for energy optimization. The production manager can use this information to analyse which configurations are more energy efficient and parameters can be reconfigured so that the line uses less energy. This information is also used to feed into the design of new energy efficient robots which will lead to the production lines using less energy and thus not only be more cost effective but also live up to national and international demands and regulations concerning energy efficiency.

Detailed reports per day shift or couple of hours are delivered to the maintenance crews. The system analyses the information and identifies potential problems. For instance, the power consumption of the devices attached to the framing station is monitored and the consumption is logged. A sudden increase in consumption points to a potential malfunction and this information is useful for both the production manager and maintenance manager.

4.2 European User Scenario

The European user scenario was extracted from the ebbits project and illustrates the transformations in automotive manufacturing of the future. The personnel working in different areas of car manufacturing used to talk about common problems, mainly related to controls architecture, communication infrastructure and monitoring systems. Now they are also talking about the common problems of energy efficiency and carbon dioxide emission.

Scenario 1: Sustainability management scenario

Making certain that a plant is working at its optimum in terms of energy consumption is extremely important to maintain a high level of company integrity in the eyes of customers and institutions.

Certifying the sustainability of their production processes has become a must for all industrial manufacturers. It is important not only to obtain certifications and to avoid fines from regulatory bodies, but also to provide a healthy environment to live and to work in.

Certification inside a production plant requires continuous collection of energy consumption data. In the past such activities were performed manually, as the devices used to retrieve the data, the related communication infrastructure and the databases for data collection required a massive investment for implementation.

All the devices used in the plant are able to collect energy consumption data, and the operator does not have to retrieve information manually, the processes have been simplified and the probability of errors reduced. The devices connect to the plant network and can be easily substituted during maintenance if necessary.

The plant informatics infrastructure is able to collect from the devices all data related to process activities, energy consumption and quality indicators. The data retrieved are analyzed and correlated by complex services distributed on the computer network, making it extremely simple for the operator to monitor the energy efficiency of each device, correlating indicators such as the production quantities and ultimately publish these data in the company's sustainability reports.

Scenario Storyline

Mario, an employee supervising the Body Welding and Assembly department of a car manufacturing plant in Italy, has experienced the complete transition from a manufacturing plant based on legacy controls architecture and energy-greedy systems towards highly flexible, efficient processes monitored and controlled by novel networked solutions.

In the past, to ensure that all production lines were ready to run, compressed air was continuously provided to the plant, also during weekends, because any shortage could change the position of the mechanical actuators, requiring human intervention to restore the correct physical start position of the plant, the only one recognized by the automatic controls to begin the production cycle. Any incorrect position of the machine might lead to dangerous crashes of the moving devices, such as robots, clamps, and slides.

The informatics infrastructure has helped eliminating entirely any kind of inefficient energy transportation system, e.g. compressed air, and with ubiquitous use of pervasive monitoring and control systems it is now possible to minimize energy consumption. The elimination of compressed air provided several positive effects. Compressed air was the most inefficient energy transportation system in the old set-up, as the losses on the line were at least half of the total energy produced. Now innovative middleware maintains the efficiency of the hardware to obtain the same performance of the pneumatic actuators.

A few years ago the EU decided that one of the strategic objectives was to reduce drastically the global emission of CO2. So Mario's company decided to implement a stringent strategy to use the minimal amount of energy. In addition to elimination of compressed air the company has developed production lines able to consume more energy when market requests are high, like a "turbo boost", and eliminate any kind of energy consumption or waste when market requests are low, to the extent of complete hibernation of the plant like bears in winter.

Mario still remembers vividly Monday mornings in the past, when the whole plant was still a mess because no one knew exactly what to do, and all documents were paper-based and distributed by hand. So every Monday morning Mario had to show up for work at 4 in the morning to have enough time to start up the entire plant.

The mechatronic[1] components are equipped with sensors able to collect and interpret in real time information on energy consumption, trajectories, sound levels etc. This information, properly correlated, can predict the presence of a possible problem in a device and notify the plant informatics infrastructure. So Mario does not have to check each singular device on the manufacturing line, and the daily work plan for each line is provided by the informatics infrastructure. He can come in Monday morning at 6 like all the other employees, because he knows that the plant never will have any crashes and it will start functioning perfectly from the very first minute of the production shift.

These days Mario works in a friendly environment, continuously connected with his peers in the plant through easy-to-use handheld devices allowing him to check the state of the whole plant. He no longer has to stay on the line to anticipate faults; providing he carries his teach pendant[2] with him.

Actually it makes no difference whether he accesses the information from his handheld device or from any PC, mobile phone, or any application hosting device, as all the information is published by a web server, and today almost all devices are able to browse web pages.

Mario prefers to use his personal wireless teach pendant because it has embedded safety functionalities, such as emergency stop button and live-man switch. The pendant also lets him move the robots on the automatic line directly, just like in the old days.

Scenario 2: Instantaneous response and predictive maintenance scenario

In the plant collisions between moving mechanical parts no longer happen; this substantially reduces down-time. Moreover, the plant will alert the maintenance staff when deviations are occurring before it is too late to remedy.

The mechatronic components are able to communicate, continuously exchanging and providing information about their position and about their maintenance status. Positional information is provided by geometric software able to calculate the distance between the devices and to slow down their movement when they are too close. This eliminates completely the possibility of crashes inside the working cells.

In the maintenance office, all the data coming from each single device are decoded and interpreted to provide to the staff a work plan detailing the activities they have to perform to keep the production plant in optimum working order.

Scenario Storyline

Alberto works in the Power Train Maintenance department of Spanish car manufacturer AutoVerde, and his main responsibility is to ensure the smooth running of all production lines whatever the prevailing circumstances.

Taking care of an automatic plant used to be an extremely difficult task. Employees in the plant needed years to learn how to become aware of anomalies that might cause production shut-downs. In some cases employees, like Alberto's former boss, developed the ability to "listen" to the sound of the machine to perceive changes in the repetitive cycle and almost prophetically forecast potentially disastrous situations.

The all-encompassing monitoring system detects any kind of internal and external variation in the production environment. Externally it detects financial fluctuations, providing information on the long-term strategy to be adopted; it detects the logistic situation, adapting the tactical production plan. Inside the plant, it detects the production flow status, faults on the machines and manages anomalous situations alerting the maintenance crew to intervene.

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[1] Mechatronics is the synergistic combination of mechanical engineering, electronic engineering, computer engineering, control engineering and systems design engineering

[2] Devices equipped with switches and dials used to control a robot's movements to and from desired points within a determined space

In the past Alberto had to wait for the decision of senior management in order to change the production strategy, and those decisions were forthcoming only after several weeks of data collection, analysis and discussion. Thanks to the new infrastructure, the data are retrieved immediately from both the external environment and internal environment, the data flow is real-time in the system, and the decisions are immediate subsequent to any change in the conditions.

A control system has been implemented which is capable of reacting to internal and external indicators in order to speed up or slow down motors and actuator movement. This way the plant only consumes energy when required. Previously this was impossible because at the higher level the control system was not able to analyze globally the plant status to properly control the overall production speed, and at lower level there was no devices able to synchronize robots and moving devices to prevent crashes when they changed speed. It was extremely hard to reduce speed of the objects because each of them reacted in a different manner, driving the machine to a sure crash.

As AutoVerde wanted to be certified as a green industry, they replaced all the devices used in the plant with new ones capable of collecting energy consumption data, so the operators no longer have to retrieve this information manually, the process is simplified and the probability of errors substantially reduced. The devices connect uniquely to the plant network, simplifying the substitution of devices during maintenance operations.

The plant informatics infrastructure collects all device data related to the process activities, to the energy consumption and to the quality indicators. The data retrieved are analyzed and correlated by complex services distributed on the network, and it is extremely simple for the operator to monitor the energy efficiency of each device, correlating indicators such as the production quantity and in the end to publish these data in the company sustainability reports.

So AutoVerde is now able to provide consolidated data on the energy consumption of the production plant, and what’s more, it has a new set of indicators that go beyond the classical OEE (overall equipment effectiveness), because they also consider the energy parameters. Those new indicators, the OEEE, provide valuable information on what strategies to implement in the company in order to conserve resources and harmonize energy consumption with production activities.

5. Requirements for the BEMO-COFRA Platform in Brazil

This section contains the condensed list of functional, non-functional, business and efficiency user requirements, extracted from the original list of user statements based on the initial vision scenarios for the car manufacturing domain. The aim of this approach is to provide a simple structured representation of requirements, to be used as a reference for the development of the first pilot applications. The list of requirements will be updated during the project lifetime, as soon as the need for features is identified. We will apply various methods to improve our understanding of user needs and to improve user-perceived qualities of the prototypes.

Each requirement listed in the following tables obtains a unique ID to refer to. The description of a requirement is a synthetic but clear description of the requirement. The rationale gives a reason why this requirement is relevant for the system and thus has been included into the table. The source gives an indication of where to find the requirement, i.e. scenario, interview or user workshop. According to the Volere scheme the requirements are divided into non-functional and functional requirements, but we will have two more divisions business and efficiency requirements.

5.1 Functional Requirements

Functional requirements are related to the use of the platform in the automotive production settings.

- Remote monitoring of the wireless sensor network
- Scalability of the wireless sensors
- Safety
- User friendly reporting of monitored data
- Monitored data
- Support for Redundant Communications using both wired and wireless interfaces in critical systems
- Devices using BEMO-COFRA should be able to interoperate with every other BEMO-COFRA device
- Workflow according maintenance map
- Data analyze
- Mobility
- BEMO-COFRA system should provide network communication robustness under high level of interference
- BEMO-COFRA system should use reliable communication protocols
- The system should provide means to connect the majority of legacy devices used in industry
- Critical data should be informed as fast as possible
- BEMO-COFRA's architecture should allow the automatic configuration of new devices
- BEMO-COFRA's architecture should be modular for insertion of new devices
- BEMO-COFRA's architecture should support a large-scale of devices
- BEMO-COFRA system should notify the maintenance team based on a hierarchical model and work schedule
- BEMO-COFRA system should provide means to locate robots along the assembly line with details about their safety area
- BEMO-COFRA system should monitor the single-radio and multi-radio WSAN modules status and performance
- BEMO-COFRA WSANs should support context-aware data transmission algorithms

- BEMO-COFRA multi-radio WSANs should support self-organization algorithms
- BEMO-COFRA WSANs should integrate routing protocols with self-healing capabilities
- Monitoring tools of BEMO-COFRA should be configurable by normal users (non software developer)
- BEMO-COFRA should provide a realistic testing tool for large scale sensor network
- BEMO-COFRA should provide a realistic testing tool for large scale sensor network
- BEMO-COFRA provide a tool to monitor performance of the Linksmart middleware
- Support for OPC interfaces
- Data fusion support
- Support for 6LowPAN based WSANs
- Communication and data exchange with ERP systems
- Monitoring of robot components for predictive maintenance

5.2 Non-functional Requirements

Non-functional requirements address the quality of the future system and are classified by various criteria according the Volere schema (usability, performance, operational requirements, maintainability, etc).

- BEMO-COFRA system should guarantee a minimum level of availability
- Network migration in Multiradio WSANs should react within an established maximum time frame
- Transmission of the same information from different devices
- BEMO-COFRA platform should provide guidelines for developers and end-users

5.3 Efficiency Requirements

Efficiency requirements are what is required in terms of energy and raw material efficiency improvements, which include the formulation of a set of business policies.

- Monitoring energy consumption
- Intelligent system analysing supplies consumption
- The BEMO-COFRA system sends periodically reports with the normal consumption

5.4 Business Requirements

Business requirements describe in business terms what must be delivered or accomplished to provide value.

- To able to perform its technical efficiency according to the automotive industry requirements
- The solution shall permit the systems integrators to perform cost efficiency by using less components (raw-material) to develop an industrial network architecture
- To permit a system integrator to install an industrial communication network applying less time and less manpower than wire/cable traditional solutions
- Future developments starting from BEMO-COFRA base platform

5.5 The European case: COMAU Europe

For the European case the requirements elicited on ebbits project will be reused for the car manufacturing domain. This section contains a condensed list of functional and non-functional user requirements that were elicited on a combined vision scenario/user workshop. This workshop was hosted by COMAU Italy Spa and moderated by IN-JET. The workshop covered two main manufacturing areas, Power Train Machining & Assembly (PWT) and Body Welding & Assembly (BWA). For each area presentations describing the business and the controls architecture were given, during and after which the participants had the opportunity to ask and answer questions. The partners also shared their visions and ideas for the future use of the ebbits platform. The visions combined with the conclusions from the Q&A sessions provided the developer partners with the foundation for eliciting the technical requirements.

Functional Requirements

- Seamless access to energy related information
- Controlling of machines/stations in manufacturing plant remotely
- Flexible integration of HW/SW components
- Retrieve manufacturing data history of any relevant event during production
- Integration of mobile sensing devices on running infrastructure manufacturing plat without interrupting running processes
- Access to energy-related information from production machines needs to be provided
- Seamless data collection
- Diagnostic component to detect and correct mal functions
- Logging of quality related information of each manufacturing part
- Producers can push notification of recalled products to customers
- System should show energy cost for different granularity of production processes
- Protection to sensitive information
- Adjust production processes according to energy price policies
- Interfacing with programmable logic controller of production robots
- Measurement points for every station in body welding
- Reliable wireless solution for new sensors
- Filter/fusion information for each operational process
- Early maintenance notification when needed
- Bring data from fieldbus network to Ethernet network
- Automatic calibration
- Automatic start up synchronization among machines
- Energy benchmarking of different granularity such as machines, processes, plants
- Support system for comparing different energy consumption among plants and corresponding processes
- Summary of energy related information at operational level for supporting management level optimizing energy use
- Recognition of energy wasting behaviours
- Waste of energy act definitions

Non Functional Requirements

- Environmental monitoring of manufacturing plant
- Higher bandwidth and range wireless connection
- Life-cycle of a robot and its components is traceable
- Resilience and adaptable to environment condition changes
- Improve air compression energy usage
- Display plant activities in real-time
- Reliability of the system should be more than 30 years
- Hardware components are able to handle harsh condition
- Scalable solution (scale up and scale down)
- Central point start the whole plant

6. Conclusion

The next steps on human-centred development process are checking the requirements through a quality gateway. The requirements will pass through a quality check to make sure that all requirements are complete (i.e. all the necessary fields are filled with meaningful values) and unambiguous. On this way the requirements will de condensed and the level of quality will be improved. This check will generate an update of this document.

As the requirements have the related work package assigned, after the quality check the requirement pass through it WP leader who will check whether its contents are correct and add it to the specification. If he believes that the requirement falls into the responsibility of a different work package, he can reassign it to the respective WP leader. He may also assign it to other people in the work package, e.g. task leaders that should take over responsibility of the requirement.

The total number of requirements will be reduced to a set of requirements within the scope of BEMO-COFRA project. Not all the requirements from the initial set will be addressed and implemented. After this new check, the working document WD2.2 Updated requirements report will be generated at least by end M7 to provide to the technical partners enough information to understand what to do for the architecture on Task 3.4 Architecture Design.

7. References

ebbits (2010), D2.4 Initial Requirements Report

ebbits (2010), D2.1 Scenarios for Usage of the ebbits Platform

Emery, F.E.; Trist, E.L. (1960) Socio-Technical Systems. In: Management Sciences, Models and Techniques, Vol. 2, London.

ISO 9241-210 (2010), ISO 9241-210:2010 Ergonomics of human-system interaction -- Part 210: Human-centred design for interactive systems.

ISO 13407 (1999), ISO 13407, Human-centered design processes for interactive systems.

Appendix A: Complete list of requirements

Brazilian Requirements

Key	Summary	Rationale	Source	Fit Criterion	Workpackage	Priority	Requirement Type	Customer Dissatisfaction	Customer Satisfaction
BEMOCOFRA-1	Remote monitoring of the wireless sensor network	Expert does not need to be present at the line.	Derived from visionary scenario.	Monitoring information remotely accessible.	WP4 Large Scale Wireless Sensor and Actuator Networks	Major	Functional	high	high
BEMOCOFRA-2	Scalability of the wireless sensors	The amount of supported devices and their response time should meet the needs of a production plant.	DOW	Simulations show that we can handle 200 nodes.	WP4 Large Scale Wireless Sensor and Actuator Networks	Major	Functional	high	high
BEMOCOFRA-3	Safety	This is an important design requirement	It was raised by the manufacturing equipment designers.	Is the safety level met.	WP2 Requirements Engineering and Validation	Major	Functional	very high	very high
BEMOCOFRA-4	User friendly reporting of monitored data	The monitored data should be displayed in a user friendly way and in different detail level, according the user's background.	Implementation scenario	All workers can comprehend the displayed information and gets the right level of detail.	WP5 Distributed Control Logic and Enabling Features	Major	Functional	high	high
BEMOCOFRA-5	Monitored data	Set of information relevant to the stakeholders.	Implementation scenario	Power consumption, water, temperatures and predictive maintenance of devices can be measured.	WP5 Distributed Control Logic and Enabling Features	Major	Functional	high	high

BEMOCOFRA-6	Support for Redundant Communications using both wired and wireless interfaces in critical systems	As wireless communication interfaces are introduced into the manufacturing plant,the presence of wired interfaces may be maintained in the case of highly critical processes. This may also be the case when the quality of the wireless communication suffers from high interferences and/or noise. A fallback or redundant interface is provided to ensure that critical systems communicate 100% of the time.	Raised by the engineers at the plant.	In no situation communication may fail.	WP4 Large Scale Wireless Sensor and Actuator Networks	Major	Functional	high	high
BEMOCOFRA-7	BEMO-COFRA system should guarantee a minimum level of availability	Each minute that production is stopped means that the company is losing money	Technical Meeting (9 December 2011)	Availability is more than 99,9% (1 minute / day of failure)	WP4 Large Scale Wireless Sensor and Actuator Networks	Major	Non-Functional	high	high
BEMOCOFRA-8	Network migration in Multiradio WSANs should react within an established maximum time frame	Network disruptions can be of dangerous in case critical information must be sent	Scenario vision	Network switching process should take less than 1 second	WP4 Large Scale Wireless Sensor and Actuator Networks	Major	Non-Functional	high	high
BEMOCOFRA-9	Devices using BEMO-COFRA should be able to interoperate with every other BEMO-COFRA device	Interoperability is required in order to avoid compatibility issues.	DoW	BEMO-COFRA devices can communicate at network layer level between each other or through LinkSmart	WP4 Large Scale Wireless Sensor and Actuator Networks	Major	Functional	high	high

BEMOCOFRA-10	Workflow according maintenance map	The notification messages are sent according to the workflow established by the maintenance map.	Customer	The rigth message is sent to the right person and if this person is not present, the system sends the message to next person on the list until find someone present at the site.	WP5 Distributed Control Logic and Enabling Features	Major	Functional	neutral	high
BEMOCOFRA-11	Data analyze	The system analyzes the raw datas and proposes a solution to the problem, so it is no more necessary speciallist and the time to solve a problem is shorter.	Customer	Messages are sent with a proposed solution .	WP5 Distributed Control Logic and Enabling Features	Major	Functional	high	very high
BEMOCOFRA-12	Mobility	The huge number of components connected on the station network difficults include a new device or change the layout.	Engineering	One sensor has your place changed on the station and it still works at the network.	WP4 Large Scale Wireless Sensor and Actuator Networks	Major	Functional	neutral	high
BEMOCOFRA-13	BEMO-COFRA system should provide network communication robustness under high level of interference	Interference could increase the BER and packet loss, which could result in loss of important information	Scenario Vision	The system should guarantee network connectivity despite the environment interference	WP4 Large Scale Wireless Sensor and Actuator Networks	Major	Functional	high	high
BEMOCOFRA-14	BEMO-COFRA system should use reliable communication protocols	The absent of reliable communication protocols could lead to loss of critical information	Scenario Vision	Delivery of messages is guaranteed	WP4 Large Scale Wireless Sensor and Actuator Networks	Major	Functional	high	high
BEMOCOFRA-15	The system should provide means to connect the majority of	The use of different legacy devices is needed to create a system	Engineers	All the devices used in the final scenario should be integrated.	WP3 Large scale distributed system architecture	Major	Functional	high	high

	legacy devices used in industry	with general application.							
BEMOCOFRA-16	Transmission of the same information from different devices	If the information collected by different devices is similar, a methodology should be employed to decide if it is necessary to communicate it.	Engineers	The communication should be avoided if the data transmitted is the same (completely redundant).	WP3 Large scale distributed system architecture	Major	Non-Functional	high	high
BEMOCOFRA-17	Critical data should be informed as fast as possible.	The data collected by the devices should be ranked according to critical requirements. Priorities should be assigned to the data and in order to communicate.	Engineers	Dangerous conditions must be eliminated to guarantee total safety.	WP3 Large scale distributed system architecture	Major	Functional	high	high
BEMOCOFRA-18	BEMO-COFRA's architecture should allow the automatic configuration of new devices	In order to increase the production, the assembly line's layout must be rearranged and for this operation to be quick, the re-configuration time must be optimized.	DoW	The user should not interfere in the configuration procedure in any moment.	WP3 Large scale distributed system architecture	Major	Functional	high	high
BEMOCOFRA-19	BEMO-COFRA's architecture should be modular for insertion of new devices	Technology is always evolving, with it, new devices will appear and the BEMO-COFRA should be able to manage them	DoW	BEMO-COFRA's architecture must be built using patterns capables of abstracting different devices	WP3 Large scale distributed system architecture	Major	Functional	high	high

BEMOCOFRA-20	BEMO-COFRA's architecture should support a large-scale of devices	Without large-scale monitoring the systems loses its purpose within the industrial scenario.	DoW	BEMO-COFRA should guarantee coverage of majority of the devices along the assembly line	WP3 Large scale distributed system architecture	Major	Functional	high	high
BEMOCOFRA-21	BEMO-COFRA system should notify the maintenance team based on a hierarchical model and work schedule	All problems should be assigned to someone capable of answering such demand therefore there must be a list of workers and what kind of problem they can attend.	Scenario Vision	The notification should take more than 1s to be sent to the workers.	WP6 Production Monitoring and Control Systems	Major	Functional	high	high
BEMOCOFRA-22	BEMO-COFRA system should provide means to locate robots along the assembly line with details about their safety area	The robot moves quickly and is extremely important to keep the its area clear at all times	Scenario Vision	The system must guide the worker to the robot and give a signal when him is to close to a robot	WP5 Distributed Control Logic and Enabling Features	Major	Functional	neutral	high
BEMOCOFRA-23	To able to perform its technical efficiency according to the automotive industry requirements	The BEMO-COFRA monitoring systems framework solution has to deliver a perform at a certain required output and data security level to be elected for a real industry environment application	Customer	Solution perform delivered at a industrial required output and data security level	WP6 Production Monitoring and Control Systems	Major	Non-Functional - performance	very high	very high

BEMOCOFRA-24	The solution shall permit the systems integrators to perform cost efficiency by using less components (raw-material) to develop an industrial network architecture	To be able to execute the same (or improve) functions from a traditional wire/cable based network in a automotive industry environment in a WSAN ambiance through a wireless reliable technology with equal or better performance than current standards in data transfer on a harsh environment	End-user	Functions of the BEMO-COFRA framework are executed with the same performance and reliability of traditional wire/cables networks.	WP4 Large Scale Wireless Sensor and Actuator Networks	Major	Non-Functional - performance	very high	very high
BEMOCOFRA-25	To permit a system integrator to install an industrial communication network applying less time and less manpower than wire/cable traditional solutions	The WSAN BEMO-COFRA monitoring systems framework solution shall be simpler and less time consuming to install than the wire/cable solution, considering that will not be necessary to prepare the wire/cable's bed around the entire industry facility, not either to have all the man power to pass the wire/cables through the cable guides and to perform a extensive test over all the necessary connections	Scenario vision	The installation of the WSAN BEMO-COFRA monitoring systems framework consumes less time and is simplier than wire/cables network.	WP3 Large scale distributed system architecture	Major	Non-Functional - performance	neutral	high

		that a wiring network requires. This will simplify and shall reduce costs to have a operational network in a real industry environment application.							
BEMOCOFRA-26	Future developments starting from BEMO-COFRA base platform	BEMO-COFRA monitoring systems framework solution should allow the future and new applications development on top of the initial base architecture to broaden the possibility to be the chosen solution for real industry applications	Scenario vision	BEMO-COFRA will be an open-source platform	WP8 Dissemination and Exploitation	Major	Non-Functional - usability	low	neutral
BEMOCOFRA-27	BEMO-COFRA system should monitor the single-radio and multi-radio WSAN modules status and performance	WSAN communication modules should be monitored in order to track their performance and detect failure or malfunctioning	BEMO-COFRA scenario	The system monitors the state and performance of the WSAN modules	WP4 Large Scale Wireless Sensor and Actuator Networks	Major	Functional		
BEMOCOFRA-28	BEMO-COFRA WSANs should support context-aware data transmission algorithms	Data transmission in WSANs should be optimized based on context (e.g., application policies) and time constraints	DoW	The system supports at least two context-aware data transmission algorithms	WP4 Large Scale Wireless Sensor and Actuator Networks	Major	Functional	high	high

BEMOCOFRA-29	BEMO-COFRA multi-radio WSANs should support self-organization algorithms	WSAN modules equipped with multiple communication technologies need to be automatically self-configured and integrated into the network, also after communication interface switching.	DoW	The system supports at least two multiradio self-organization algorithms	WP4 Large Scale Wireless Sensor and Actuator Networks	Major	Functional	high	high
BEMOCOFRA-30	BEMO-COFRA WSANs should integrate routing protocols with self-healing capabilities	n WSANs, routing operations could be hindered by specific failures or malfunctioning; failure impact should be reduced.	DoW	The WSAN supports at least one routing protocol with self-healing mechanisms	WP4 Large Scale Wireless Sensor and Actuator Networks	Major	Functional	high	high
BEMOCOFRA-31	Monitoring energy consumption	The energy consumption of car manufacturing industry has increased with the installation of automation devices and unit price for energy consumption has increased as well.	Scenario vision	Energy consumption reports	WP6 Production Monitoring and Control Systems	Major	Non-Functional - performance	high	high
BEMOCOFRA-32	Intelligent system analysing supplies consumption	Beyond monitoring energy consumption the system should be able to analyse the datas, creating reports for each station and extract a detailed energy consumption report for each specific part or device within	Scenario vision	Friendly reports with details of selected monitored values	WP6 Production Monitoring and Control Systems	Major	Non-Functional - operational	neutral	high

		the station							
BEMOCOFRA-33	The BEMO-COFRA system sends periodically reports with the normal consumption	The normal consumption information analyse the possibility for energy optimization. The production manager also can use this information to analyse which configuration are more energy efficient. This information also can be used to feed the design development of new energy efficient devices, as robots.	Scenario vision	Reports with the normal consumption energy are sent periodically to the line manager/product designer.	WP6 Production Monitoring and Control Systems	Major	Non-Functional - operational	neutral	high
BEMOCOFRA-34	Bemo cofra platform should provide guidelines for developers and end-users	Without a clear documentation and best practices guideline the developers and users will get confused.	FIT internal workshop	the documentation contains code examples, workflow, deployment guidelines	WP7 Solution Integration and Deployment	Major	Non-Functional - usability	very high	neutral
BEMOCOFRA-35	Monitoring tools of bemo-cofra should be configurable by normal users (non software developer)	The monitoring needs might change in the future and new software development for every changes is costly and not feasible.	Requirement workshop	normal user can configure the monitoring application simply by drag and dropping widgets.	WP6 Production Monitoring and Control Systems	Major	Functional	neutral	very high

BEMOCOFRA-36	Bemo cofra should provide a realistic testing tool for large scale sensor network	the budget of the project is not sufficient to create large scale testbed consisting physical devices	The first technical meeting in Recife	the testing tool could record and simulate the radio interference inside manufacturing plant.	WP3 Large scale distributed system architecture	Major	Functional	very high	low
BEMOCOFRA-37	Bemo cofra must provide an integrated monitoring tool (integrate different monitoring tools into a platform)	Users do not want to be confused with having to open different applications	First technical meeting in Turin	User is able to start different monitoring tools through one application.	WP6 Production Monitoring and Control Systems	Major	Functional	high	neutral
BEMOCOFRA-38	Bemo cofra provide a tool to monitor performance of the Linksmart middleware	The administrator needs to see the network performance to diagnose a problem of the system.	First technical meeting in Recife	The Linksmart administrator is able to see linksmart throughput in terms of events in and out the event manager, soap messages in and out the network manager, number of event and soap messages lost, connected proxies in a gateway, the gateways in the networks.	WP5 Distributed Control Logic and Enabling Features	Minor	Functional	low	neutral
BEMOCOFRA-39	Support for OPC interfaces	In order to integrate existing manufacturing devices we need to support OPC since it is the de-facto industry standard	CNet requirements workshop	BEMO-COFRA can communicate using OPC	WP6 Production Monitoring and Control Systems	Major	Functional	very high	very high
BEMOCOFRA-40	Data fusion support	It must be possible to extract monitoring data from several devices/source and integrate that into one	CNet requirements workshop	Data fusion functionality available	WP6 Production Monitoring and Control Systems	Major	Functional	high	high

		semantically enriched monitoring report.							
BEMOCOFRA-41	Support for 6LowPAN based WSANs	It must possible to integrate and extract data from standards based WSAN, for instance Contiki running 6LowPAN.	CNet requirements workshop	BEMO-COFRA can communicate using 6LowPAN and Contiki.	WP6 Production Monitoring and Control Systems	Major	Functional	high	high
BEMOCOFRA-42	Communication and data exchange with ERP systems	In order to provide users with relevant decision support information BEMO-COFRA needs to integrate and exchange data with existing ERP and other control systems.	CNet requirements workshop	BEMO-COFRA can export data to relevant ERP and control systems.	WP6 Production Monitoring and Control Systems	Major	Functional	very high	neutral
BEMOCOFRA-43	Monitoring of robot components for predictive maintenance	We want to be able to predict the failure of robot components to prevent damage in order to steer the maintenance work and to save costs.	Scenario and requirement workshop in Recife 5-7.12.2011	In 99,9% of the cases the Bemo-Cofra system will be able to detect an upcoming failure of a component, before the component really fails.	WP6 Production Monitoring and Control Systems	Major	Functional	low	very high

European Requirements

Key	Summary	Rationale	Source	Fit Criterion	Priority	Requirement Type	Customer Dissatisfaction	Customer Satisfaction
89	Scalable solution (scale up and scale down)	adjustment to desired number of production, require to add or reduce machines	Comao Workshop in Turino	configuration of scaling up / down a plant can be achieved in max 8 hours.	3	Non-Functional:Maintainability	very high	very high
103	Automatic calibration	Calibration is still done manually it is error prone, and takes time.	Comao Workshop in Turino	75% of existing manual calibration is done automatically.	1	Functional	very high	high
104	automatic start up synchronization among machines	starting up machines in a plant is complicated such as the order of machines, min temperature etc.	Comao Workshop in Turino	a plant can be "re-started" automatically in less than an hour.	2	Functional	very high	very high
84	Interfacing with Programmable Logic Controller of production robots	Production automation is controlled through PLC	Comao Workshop Turino	Software and hardware interfaces to PLC is defined	3	Functional	very high	very high
105	reduce water consumption in PWT	water consumption for cooling and lubricating purposes in PWT is really high (300-500 lt./minute)	Comao Workshop Turino	10% of water consumption can be reduced	4	Non-Functional:Operational	high	high
49	Access to energy-related information from production machines needs to be provided.	Energy-related information is measured by some of the operational machines (e.g. in the production plant), but it is not distributed into a network.	COMAU scenario workshop (10/19/2010).	If any machine provides access to energy-related information, ebbits distributes this information to all interested parties.	2	Functional	very high	neutral
106	Energy benchmarking of different granularity such as machines, processes, plants	Management would like to know how effective the energy is used in different operational levels.	Comau Workshop	Management can do benchmarking in different operational level	1	Functional	very high	very high

109	Recognition of energy wasting behaviors	Help decision makers to optimize energy usage	Comau Workshop	Decision makers are alerted when energy wasting takes place	4	Functional	neutral	neutral
147	Waste of energy act definitions	Some users are waisting energy without realizing/being conscious that there are better alternatives.	Comau Workshop	Energy wasting behaviors are modeled	3	Functional	very high	very high
85	3 Measurement Points for every station in body welding	energy cost that can be calculated includes: lightings, processes, energy for welding	Comau Workshop in Turino	3 measurement points are covered	3	Functional	very high	very high
86	Reliable wireless solution for new sensors	cable costs are high and due to harsh condition, cable might break	Comau Workshop in Turino	sensors are using wireless connection.	3	Functional	high	high
87	reliability of the system should be more than 30 years	a production plant of trucks can runs for 30 years	Comau Workshop in Turino	99% of the time system is able to run 30 years.	2	Non-Functional:Operational	very high	very high
88	hardware components are able to handle harsh condition	harsh condition damage electronic devices	Comau Workshop in Turino	devices fulfill manufacturing insulation standard for cables and sensors.	3	Non-Functional:Operational	high	high
91	Filter/fusion information for each operational process	Each process needs different resolution of information	Comau Workshop in Turino	Processes only get information needed	3	Functional	high	high
107	Support system for comparing different energy consumption among plants and corresponding processes	Management would like to learn from other plants if they use energy more efficiently.	Comau Workshop in Turino	Management can compare energy profile of plants.	2	Functional	high	very high
108	Summary of energy related information at operational level for supporting management level optimizing energy use	Operational management needs a summary of energy related information that help them making decision to optimize the energy usage.	Comau workshop in turino	Management can access operational information.	3	Functional	very high	high

90	central point to start the whole plant	machines have to be started in the right order.	Comau Workshop Turino	the whole machines in a plant can be started from a central point.	3	Non-Functional:Operational	very high	very high
92	Early maintenance notification when needed	Early maintenance prevent permanent damage to the robots, ensure the reliability of robots	COMAU Workshop Turino	Users/technicians are notified if robots need maintenance	4	Functional	high	high
93	Bring data from fieldbus network to ethernet network	Analytics is done by ERP program on a computer that work on TCP/IP.	Comau Workshop Turino	Analytics software can analyze data from manufacturing robots	3	Functional	high	high
47	Resilience and adaptable to environment condition changes	Environmental changes such as lighting, temperature affect the results of manufacturing process. so far machines are tuned manually by technicians. adapting to environmental condition can lead to reducing energy consumption e.g.: reduce heater temperature when it's warm outside.	During ebbits manufacturing scenario workshop in Oct 2010 this is issue had been raised by a COMAU employee.	Machines can adapt its parameters adapting to environmental changes.	2	Non-Functional:Operational	high	low
37	Higher bandwidth and range of wireless connection	Currently, BT is used for wireless communication. It supports ranges <50m. Especially, the bandwidth is too low: max 24 MBit/s.	During ebbits manufacturing workshop (19th Oct, 20010) a COMAU employee of the Body Welding & Assembly unit raised this issue.	Communication range and in particular bandwidth are considerably higher.	3	Non-Functional:Performance	very high	low

38	Flexible Integration of HW/SW components	The process to set-up a plant and to fine-tune each machine costs at least a day. In this sense, the integration of new HW/SW must be very easy to not disturb the overall process.	During ebbits manufacturing workshop (19th Oct, 20010) COMAU (Fulvio) that they need to have this functionality for deployment.	In plug'n'play manner new HW/SW components can be easily integrated into an existing system without loosing much time.	2	Functional	high	low
36	Controlling of machines/stations in manufacturing plant remotely	To optimize production process.	During ebbits manufacturing workshop (19th Oct, 20010) COMAU employee (Fulvio) raised this issue.	Relevant stations that operate automatically can be started/stopped via remote calls.	3	Functional	high	low
64	Historical data should be recorded persistently.	Quality is very important inside an assembly line as it is the essential parameter used for force tests or lack tests.Furthermore, if failures are detected lately when a car is already in the market, but shows some lack, the production history can be traced to find the devil in the detail.	During ebbits manufacturing workshop (19th Oct, 20010) COMAU employee (Fulvio) raised this issue.	Quality related information is logged inside a proper carrier medium.	1	Functional	high	low
35	Hazardous Environmental Monitoring of Manufacturing Plant	Currently the environment of a plant provide is not monitored properly. However, this is quite important to guarantee the safety of an operator.	During ebbits manufacturing workshop (19th Oct, 20010) COMAU employee (Roberto) raised this issue.	The safety of the operator is improved by 20% on the basis of environmental input information.	1	Non-Functional:Maintainability	very high	low

60	Improve air compression energy usage	Air compression is one main energy guzzler. Only 40% of air can be transferred effectively.	During ebbits manufacturing workshop (19th Oct, 20010) COMAU employee (Roberto) raised this issue.	More than 40% of air can be transferred effectively (@Roberto is this realistic?)	3	Non-Functional:Operational	very low	very high
21	Seamless Access to Energy Related Information	Energy-related information is only available right at the Human-Machine Interface at the respective station.	During ebbits manufacturing workshop (19th Oct, 20010) COMAU employee raised that their customers and themself as would like to have this functionality. Further, from 2012 all machines will have energy certification, similar to fridges or washers.	At least three different types of devices within the enterprise (manufacturing plant, management, administration) that feature a user interface can display energy-related information.	3	Functional	high	low
39	Retrieve manufacturing data history of any relevant event during production	If production defects are recognized, it is helpful to look at the production process history in order to find out what caused the defects.	During ebbits manufacturing workshop (19th Oct, 20010) COMAU employee raised this issue.	Any manufacturing relevant (pressure, energy consumption, temperature, humidity, time etc) data is retrievable.	1	Functional	very high	very low
40	Life-cycle of a robot and its components is traceable	At the moment the life-cycle of a robot's component is not predictable. However, being able to predict its life-cycle could support to avoid deviations during production.	During ebbits manufacturing workshop (19th Oct, 20010) COMAU employee raised this issue.	Based on analyzing data of real field tests the life-cycle can be predicted properly.	2	Non-Functional:Maintainability	neutral	very high

41	integration of mobile sensing devices on running infrastructure manufacturing plant without interrupting running processes	In brown field it is too risky or too expensive to stop production in order to install missing sensors (e.g. smart meter).	During ebbits manufacturing workshop (19th Oct, 20010) COMAU employee raised this issue.	It is possible to enhance a station/machine/robot with mobile sensing devices to gather data.	2	Functional	very low	very high
42	semantic relationships between data	Currently, any data is stored in a simple database. Hence, data is availabe, but cannot be interrelated intelligently.	During ebbits manufacturing workshop (19th Oct, 20010) COMAU employee raised this issue.	Data can be queried and inferred in order.	1	Functional	very high	very low
61	Display plant activities in real-time	To observe the complexity of a production inside the plant.	During ebbits manufacturing workshop (19th Oct, 20010) COMAU employee raised this issue.	A user-friendly interface is provided to the relevant stakeholders to view activities inside the plant.	3	Non-Functional:Usability	high	low
62	Seamless data collection	Data collection is the required input for simple and complex analysis in both manufacturing and traceability scenario.	During ebbits manufacturing workshop (19th Oct, 20010) COMAU employee raised this issue.	Both mobile or static sensors are affixed to any medium (animal, robot etc) in order to sense the environment.	1	Functional	very high	very low
63	Diagnostic component to detect and correct malfunctions	If a malfunction has slipped in the plant it should be corrected ASAP. In fact, if possible any fault behaviour should be prevented at all.	During ebbits manufacturing workshop (19th Oct, 20010) COMAU employee raised this issue.	Malfunctions or strange behaviour of machinery are recognized early enough.	3	Functional	neutral	high
78	System should provide location tracking of the stocks/livestocks	Users sometimes lost track where the goods /animals are.	TNM Workshop Copenhagen, Comau Workshop Turino	Users can identified where the stocks / livestocks are	1	Functional	very high	very high

65	producers can push notification of recalled products to costumers	producers want to avoid getting sued because the weren't fast enough notifying consumers about recalled products. the common methods is through TV, Radio, Website, for cars can be through phones	TNM Workshop in Copenhagen, Comau Workshop in Turino	customers who bought the products are notified within 24 hours since products being recalled	2	Functional	high	high
81	System should show Energy Cost for different granularity of production processes	Energy cost at different levels is needed to do benchmarking of operational processes.	TNM Workshop in Copenhagen, Comau Workshop in Turino	Each automated process, machine is able to show energy cost	1	Functional	very high	very high
83	Adjust production processes according to energy price policies	reduce production cost by taking into account energy price policy from energy provider.	TNM Workshop in Copenhagen, Comau Workshop in Turino	at least production speed and start/stop production can be adjusted according to the price of energy.	2	Functional	high	high
82	System should provide access restrictions to sensitive information.	Some sensitive information endanger company existence.	TNM Workshop, COMAU Workshop	System provides access restrictions to sensitive information.	1	Functional	very high	very high

Appendix B: Organisation diagram

The typical organisation diagram for a car manufacturing plant is shown in the Figure below.