MAESTRI

Total Resource and Energy Efficiency Management System for Process Industries

Deliverable 1.4

Initial Requirements Report

Date: 29/02/2016

WP1 Requirements Engineering

T1.4 Initial Requirements Elicitation

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Executive Summary

For the initial requirements elicitation we used a user-centred approach with user workshops at each demonstration site interviewing representatives from the involved processes that are relevant to the MAESTRI project.

From those interviews and the deliverable D1.3 MAESTRI Business Cases we derived in total 34 requirements (functional and non-functional) which now will be the basis for the ongoing work. New requirements will be added and the existing ones will be refined and worked on according to the MAESTRI requirements process that is also documented in this deliverable.

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Abbreviations

IPR – Intellectual Property Rights

UCD – User-Centred Design

WP – Work package

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1 Introduction

1.1 Purpose, context and scope of this deliverable

The purpose of this deliverable is to give a systematic formalization of an initial set of relevant stakeholder requirements and sub-system requirements. These requirements will guide the developments in the technical work packages, and therefore, this deliverable will be the first common source of user requirements for the MAESTRI consortium. The list of requirements in this document reflects the work performed in Task 1.4 – Initial Requirements Elicitation and emerged from two workshops conducted in Portugal and Germany with representatives from the industry partners where demonstration activities will be performed: GLN Plast, JWO, MCG and Worlée.

1.2 Deliverable Organization

This deliverable is organized as follows:

- Chapter 2 describes the methods and principles applied for the user-centred development of software in general.
- Chapter 3 instantiates these methods and principles for the specific properties of the MAESTRI project.
- Chapter 4 lists the initial set of functional and non-functional requirements for a future MAESTRI platform.
- Chapter 5 provides a conclusion regarding the first three months of the requirements engineering process.
- Appendix A illustrates the complete initial requirements in a table that follows the Volere template.

2 Methods and Principles of Human-Centred Development

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 deliverable is the first result of the process of requirements engineering that the MAESTRI project has started. Requirements engineering is a continuous iterative process driven by an adopted user-centred design (UCD) approach as opposed to a stage or phase realized once in the beginning of a project. An incomplete requirements analysis tends to lead to problems later in the system development and refinement phases. Therefore it is important to continue the user-centred design process outlined in this document. As a consequence, this document should be considered as an initial version of the requirements that will be the basis for updated and changed requirement reports as new requirements arise or outdated disappear in the iterations of the project.

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The general approach to requirements gathering involves following activities:

- Elicitation. Discovering, extracting and learning needs of stakeholders. It includes a domain analysis that helps to identify problems and deficiencies in existing systems, opportunities and general objectives. Scenarios are part of this activity.

- Modelling. Creating models and requirements, looking for good understanding of them and trying to avoid incompleteness and inconsistency.

- Negotiation and agreement. To establish priorities and to determine the subset of requirements that will be included for the next phase.

- Specification. Requirements expressed in a more precise way, sometimes as a documentation of the external behaviour of the system.

- Verification/Validation. Determining the consistency, completeness and suitability of the requirements. It could be done by means of static testing (using regular reviews, walkthroughs or other techniques) and prototyping.

- Evolution and management. The requirements are modified to include corrections and to answer to environmental changes or new objectives. It is important to ensure that requirement changes do not produce a large impact on other requirements. Requirement management means to face those modifications properly, to plan requirement identification and to ensure traceability (source, requirements and design traceability).

It is important to underline that most of these activities are performed in parallel.

2.1 ISO 9241-210 Standard

The ISO 9241-210 (ISO, 2010) "Ergonomics of human-system interaction" gives guidance on human-centred design activities throughout the life cycle of computer-based interactive systems.

Essential principles in this process are

- Multi-disciplinary design

- Iteration of design solutions

- Appropriate allocation of function between user and technology

- Active involvement of users and a clear understanding of user and tasks requirements

The multi-disciplinary design is given by the expertise of the people from the consortium members, which include psychologists, computer scientists, usability engineers and designers. The iteration of solutions is implemented in the MAESTRI work plan.

The human-centred approach implies an iterative life cycle in a project. A system is perceived as a socio-technical system, i.e. the novel technology is a fit between a technical system and its usage. 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

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available, users can try it out 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 MAESTRI three cycles are planned for the project lifetime, aiming at validated prototype specifications, including concepts of usage.

One of the core tasks of user-centred design 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 literature has a lot of examples demonstrating that end users have to bridge the large gap in understanding especially in projects that apply a waterfall model. Clark, Lobsitz & Shields, (1989) show that evolutionary or iterative approaches drastically reduce this gap.

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.

2.2 The Volere Schema

The ISO 9241-210 standard does not prescribe specific methods to achieve these goals; they are to be chosen according to the current state of the art and what is appropriate under individual project circumstances. Based on practical experiences from other R&D projects, we have devised a scenario-based approach, combined with user workshops and expert analysis, based on the structure proposed by Robertson & Robertson (see Robertson and Robertson, 1999) for mastering requirements.

The Volere process recommended by Robertson & Robertson ensures that all important aspects of requirements are carefully addressed and that the methods applied have proven their value in practical work. The details of the applied process within MAESTRI are explained in the subsequent Chapter 3, whereas the important aspects of the

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requirement description according the Volere schema are addressed in Section 3.5. It has been proven to be of great value to put in the effort to define the global constraints affecting the project and the fine-grained distinction of different types of functional and non-functional requirements. Furthermore the definition of customer satisfaction and dissatisfaction helps in prioritizing the requirements and the proper definition of a Fit Criterion and the rationale so that the reader understands the reasoning behind it helps in evaluating if the requirement has been implemented correctly. The philosophy of Robertson & Robertson is very much in line with ISO 9241-210 and allows a structured processing of the requirements assuring that they remain always applicable and testable.

2.3 Sources for the Derivation of Requirements

The requirement derivation process has to be founded on specific sources for information. The two classical sources are scenarios and field studies, which consist of interviews and ethnographical methods like participatory observations of the domain context and experimental testing of existing solutions. Additionally, requirements can come from state of the art analysis and new developments within the domains represented by the industrial partners in the MAESTRI project.

2.3.1 Scenario Discussion

Scenarios have proven their potential to communicate project goals and design solutions among all stakeholders and are widely used to discover and understand users' goals and system requirements. Scenarios can be used at all stages of a project, and for various purposes. In particular, scenarios are the first tangible artefact a project can possibly produce, and are therefore suited to start user involvement very early. Scenarios can capture and illustrate features of a system, modes of its usage, and the benefits for users. Scenarios can be written at several levels of detail, they can tell about the current as well as future states of a socio-technical system. Scenarios can focus on normal usage, but can also be used to explore critical cases, limitations or even catastrophes. Scenarios are useful to support discussion among project team members as well as with prospective developer-users. Scenarios can also be seen as part of the documentation and specification of a system. There is huge amount of literature concerning scenario-based approaches (see: Carroll (2000), Sutcliffe (2003), Weidenhaupt et al. (1998) and Dzida et al. (1999)).

From the scenarios and storylines, a systematic formalisation of all relevant user requirements and subsystems requirements will be derived.

The basis will be user-centric requirements originating from the ecosystems of heterogeneous stakeholders. These include functional requirements, energy requirements, business requirements and trust, privacy and security requirements. The non-functional societal requirements will include requirements related to ethics, inclusion and data protection, quality of use, professional liability, IPR issues, legal and regulatory needs, etc.

2.3.2 User Workshops

The user workshops conducted in the initial phase were focus group interviews aimed at acquiring knowledge about the specifics of the domain and the working procedures from the industrial partners.

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A focus group is a qualitative research method using a group of experts, in this case experts covering the complete workflow within the industry partner´s organization. Focus groups are an important tool for acquiring feedback regarding new ideas and potential areas for improvement. In particular, focus groups allow discussing and testing of a new product idea. This can provide invaluable information about the potential market acceptance of the product idea.

The workshops were conducted mainly with one-on-one interviews in order to collect feedback that is unbiased from group effects that can occur when different kinds of personalities are involved in group discussions. We also conducted workshops in an interactive group setting, where participants are asked questions by a moderator and are free to discuss with other group members. They enable the collection of information about the working environment, which includes a survey of the existing IT infrastructure, and thus, the identification of preliminary requirements and restrictions from the ability to interface with these systems. The selected interview partners covered all areas of the working processes that are relevant to the MAESTRI project.

The combination of observation and interviews has proven its potential to deliver the best insight into understanding the processes among all stakeholders. Observation is of great value especially in the initial stages of a project. It is often more target-oriented to observe users in their domain context and their activities than to ask them in interviews.

Interviews can be used at all stages of a project, and for various purposes. During their work, it is more convenient for users to explain what they are actually doing and why. In order to create a more comfortable and conversational situation, it is common practice to perform semi-structured interviews. These interviews loosely follow specific guidelines and a list of questions, but leave room for a spontaneous adaptation of the progress and development of the conversation.

The documentation of this information is done either by taking direct notes or, if all details must be captured, by videotaping the participants while using of the system and capturing the environment by taking pictures or painting images.

In general, focus groups support the collection of ideas about how to optimize the use of the new technology. Focus groups are low in cost, one can get results relatively quickly, and they can increase the sample size of a report by discussing with several people at once.

The initial requirements that we obtained are the result of four one-day focus group workshops that we have conducted at GLN Plast, JWO, MCG and Worlée premises.

3 User-Centred Design Procedure in the MAESTRI project

An essential property of the UCD approach is that it has to be adapted to the specific requirements of the individual project. This chapter gives an overview on how the standard procedure has been instantiated and adapted to the MAESTRI project.

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3.1 Initial vision scenario

A scenario is an acknowledged way of communicating the vision of a particular system, as well as to explain and document requirements. Deliverable 1.1 "MAESTRI Platform Usage Scenarios" documents the work undertaken in task T1.1 "Scenario Thinking" and provides top-level user requirements in the form of vision scenarios of future use of the MAESTRI platform in the areas of the three main pillars – Efficiency Framework, Management System and Industrial Symbiosis. The next step produces technically oriented scenarios focusing on the deployment and use of the MAESTRI platform. These scenarios address technical questions referring to the platform and its components.

Creating scenarios of end-user behaviour and interaction with platform functionality is an extremely useful instrument for identifying key technological, security, socio-economic and business drivers for future end user requirements. The scenarios provide a vision framework for the subsequent iterative requirement engineering phase.

3.2 Derivation of Platform Usage Scenarios

From the main vision scenario more technical scenarios have been derived that were used to elicit requirements for the future MAESTRI platform. Following the UCD cycle, the scenarios will be continually refined in the next steps. The technical scenarios were tentative, trying to capture the context of use for a certain user role and to illustrate how the MAESTRI platform might support them. Such technical context scenarios illustrate the benefits and functionality of a system for certain user groups with their typical tasks and goals (see Dzida, 1999). They describe the users' view of the usage of a system within the current context of work and the envisaged improvement of tasks. Scenarios normally do not explicate details of interaction, which is left for a later stage when mock-ups are available. These technical scenarios were elaborated for different work of context aspects and specific to the problems and questions within all technical work packages.

It is important to note that the technical scenarios were meant as means for discussion with users. The scenarios do not contain requirements, but help the users and experts generate the requirements.

3.3 User Workshops

User workshop took place at each location of a demonstration site in Portugal at GLN Plast and MCG in November 2015 as well as in Germany in January 2016 at Worlée and JWO. In Portugal FIT led the user workshops and in Germany ATB joined FIT in conducting the workshops at Worlée and JWO. The workshops included a tour through the production areas in order to get a better understanding of the processes involved. The interviews were held either as individual interviews where only one person from the company was present or in a group setting where several people from the same company participated.

The purpose of the user workshops was to get insight into roles, processes, exceptions, problems and stakeholders involved in the operation of their technology. The workshops started with a short introduction into MAESTRI and its goals and what the goals were for the user workshops. The intention was to get a broad understanding of the work performed in each area (context of use). This allows to better focus the following activities within MAESTRI and through the summary reports from each demonstration site to share

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the knowledge gained. Additionally, we wanted to gather requirements in a first step and to be able to elaborate on the technical scenarios. During the interview and discussion phase, the users were asked what support they would want to have and what their requirements would be in order to improve their work environment. This way, the users could express ideas from which to derive requirements to the MAESTRI platform.

3.4 Requirements derivation

The main task after the completion of workshops and interviews was the consolidation of the information gathered from the discussions. The output of the discussions and interviews are user statements. The analysis of the original users' statements in the respective workshops led to the elicitation of requirements at different levels of detail and their aggregation in a structured way. Such user feedback to technical scenarios may relate to various aspects of the system and its use, and have been classified according to the Volere schema (see Robertson and Robertson, 1999).

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 and the context of use)
- Performance requirements (how fast, big, accurate, safe, reliable, etc.)
- Operational requirements (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)

Look and feel, usability and cultural requirements are of secondary relevance for the assessment of requirements for a software platform, but are of high importance for the assessment of qualities and aspects of the user interfaces to be developed. The current set of user requirements can be found in Chapter 4 of this deliverable and thus has become accessible for all users and also traceable for evaluation of design solutions.

3.5 Requirement description (Volere Schema)

The workflow to ensure that all necessary details and procedures in the Volere schema are adhered to is rather complex, and it was decided to support this process with a tool for all partners within the project.

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We decided to use JIRA, which is a web based bug tracker that allows implementing and tracking the workflow of the Volere schema. Figure 1 shows a screenshot of JIRA with a list of open requirements.

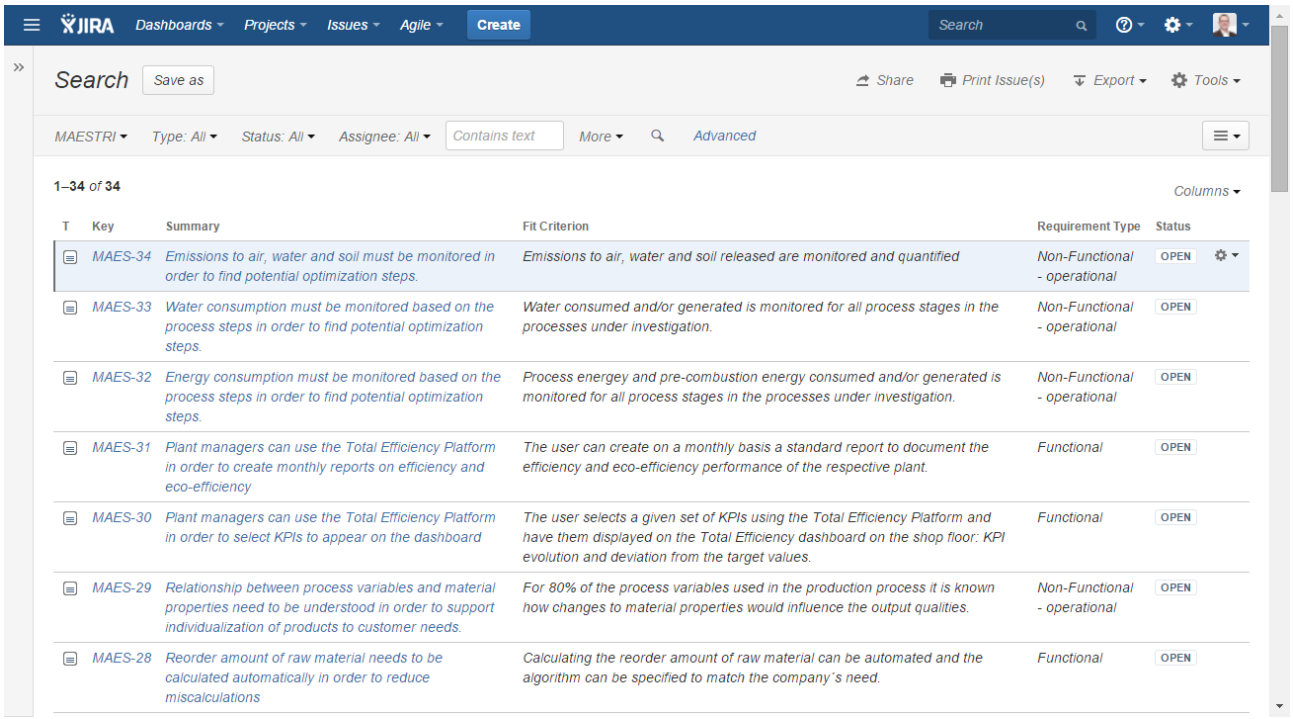

Figure 1: Screenshot of JIRA with a list of requirements

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", "Trivial", and "Nice to have". The rating was carefully assigned and was 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, or through discussions within the consortium, by vision and technical scenarios or by the c.
- The assessment of customer satisfaction and dissatisfaction if this requirement is achieved or missed, respectively.
- The estimation if the requirement is within the scope of the project.
- The component that the requirement is associated to.

The summary of a requirement contains a one-sentence description of the requirement. The description tells about 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

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makes to the product's purpose. The rationale contributes to the understanding of the requirement.

The Fit Criterion is the quantified goal 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 quantifiable manner. The Fit Criterion sets the standard to which the developer constructs the product.

Figure 2 shows a screenshot of JIRA with a requirement in edit mode:

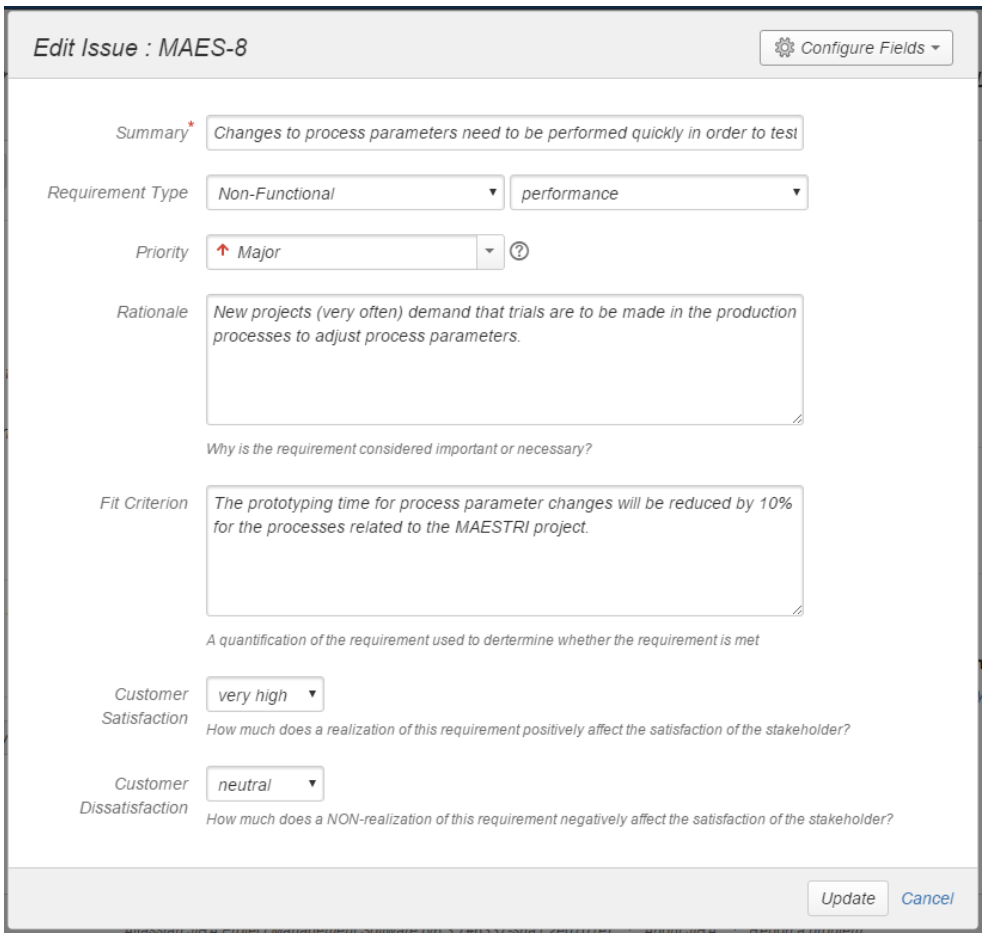

Figure 2: Screenshot of JIRA with a requirement in the edit mode

In order to express dependencies and conflicts among requirements, JIRA allows the definition of links between two requirements.

3.6 Requirements workflow

Two different user groups are involved in the requirements process:

- Reporters: This group contains all project members.
- Assignees: Each newly reported requirement is assigned to a single person – the assignee. The assignee is responsible for passing the requirement through the quality check.

Figure 3 displays a requirement's possible status and the possible transitions between the status.

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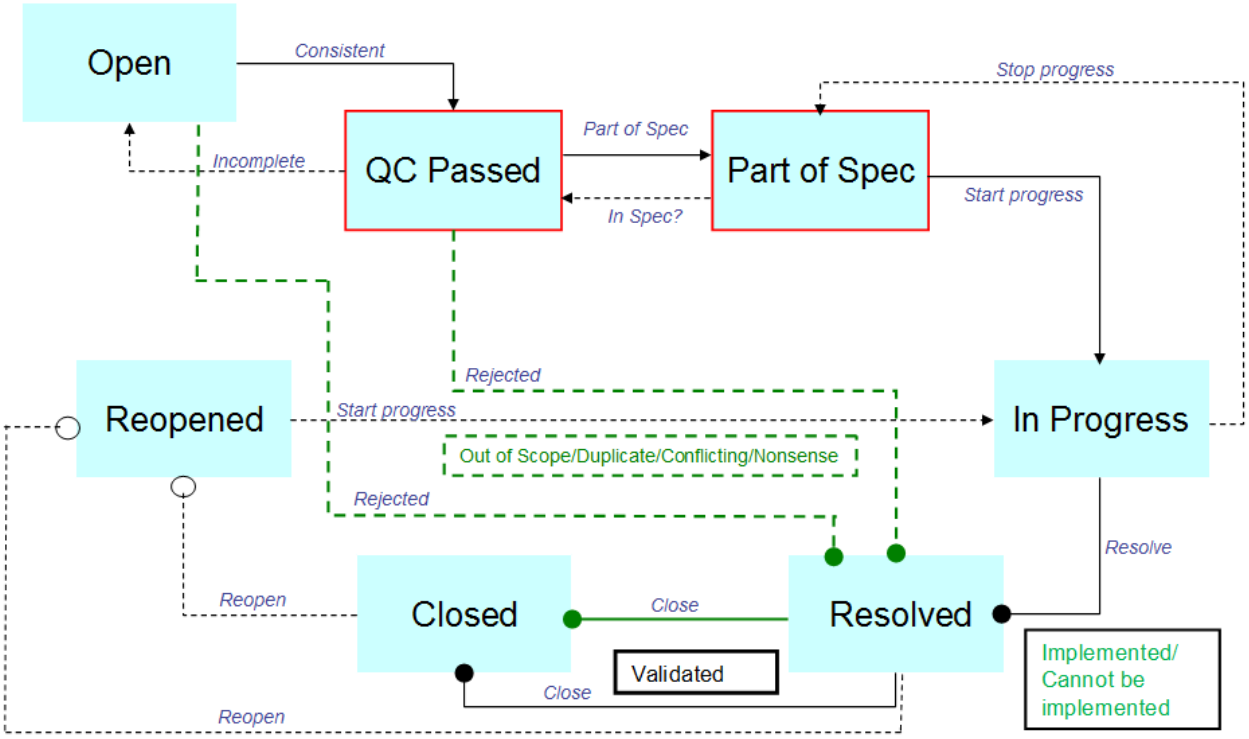

Figure 3: Structure of the Requirements Workflow

When a requirement is entered by a reporter, it gets assigned the status *open*. A project member assigns the requirement to an assignee. If it is complete and unambiguous, the assignee changes the requirement's status into *quality check passed*. Ideally, the assignee and the reporter are different project members. A quality check passed requirement has its text fields filled in sensibly, with appropriate values chosen from the drop-down lists. The priority must be selected to make it possible to rank requirements in relation to each other.

A requirement can fail to pass the quality gateway for three reasons:

1. A requirement can be incomplete. Some fields may have meaningless entries like '?'

2. A requirement can be ambiguous; certain terms are not clearly specified

3. A requirement is too general or does not make sense at all; this can happen for example when the reporter of the requirement does not include enough detail information in order for another person to understand the reasoning behind it.

If a requirement fails the quality check, it gets rejected for one of three possible reasons: incomplete, ambiguous or does not make sense. Once the requirement is updated properly, its status is changed to *reopened*. This status equals exactly the initial status *open* and the quality check process restarts. The status *reopened* is used to indicate that a requirement went through the quality control at least once. This helps to detect requirements that are yet untouched.

Eventually, all requirements will pass the quality gateway. The next step is to decide whether a requirement becomes part of the specification, or whether it is to be rejected. A requirement can be rejected for two reasons:

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1. It is a duplicate of another requirement.

2. It is out of the project's scope.

If a requirement's status is either *rejected*, *part of specification* or *duplicate*, a requirement is said to be resolved. If its status is *part of specification*, it means that It will be implemented and validated.

4 Overview of functional and non-functional requirements

This section contains the condensed list of functional and non-functional user requirements, extracted from the original list of user statements based on the initial user workshops with the industry partners. The aim of this approach is to provide a simple and structured representation of requirements, to be used as a reference for the development of the first iteration of the platform and the applications. The list of requirements will be updated during the project lifetime, as soon as the need for new or modified features is identified. We will apply various methods to improve our understanding of the user needs and to improve the user-perceived qualities of the prototypes. In particular, we will review the user requirements during the evaluation of the first application prototypes in order to get the second, improved set of user requirements (see for example Schmidt-Belz et al., 1999).

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 column source gives an indication of where the requirement was generated from, i.e. scenario or interview. According to the Volere scheme the requirements are divided into non-functional and functional requirements.

4.1 Functional requirements

User statements that explicitly refer to the functionality of the future MAESTRI platform are called functional user requirements.

In the following table you can find an overview of the initial functional requirements:

Req-Id	Summary	Rationale
MAES-1	The platform will store the monitoring data permanently in order to access it later	For the optimization of processes one needs to analyse historic data to identify wasteful activities and develop effective counter-measurements. The data should include timestamps in order to retrieve data based on a specific timeframe.
MAES-12	The production manager is able to identify the most valuable use of scrap parts in order to	Even if a company is already selling waste and scrap parts they probably do not know all of the alternatives how this could be monetized and could do so with such a functionality in a much more effective way.

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	maximize the revenue.	
MAES-28	Reorder amount of raw material needs to be calculated automatically in order to reduce miscalculations	Calculating the reorder amount for raw material is not automated so users use Excel and the result depends on the experience of the user with the processes involved.
MAES-2	The system administrator can specify the time interval for monitoring the data in order to reduce the amount of data to be processed.	The system administrator of the MAESTRI platform can specify a time interval for each of the sensors that will be monitored in order to reduce the amount of data that will be processed within the platform. Temperature sensors monitoring e.g. the room temperature need to monitored in longer intervals (like every 5 minutes) compared to temperature of a plastic injection machine where we want to analyse the temperature curve of one cycle time and this needs to be done in a much shorter interval (like every 500ms).
MAES-15	The supply chain manager is able to analyse historical data about problems the supply chain in order to get decision support for future planning	The supply chain manager is able to identify reasons for disturbances in production planning caused by supply chain events based on the analysis of historical data (comparison of plan data and actual data). Results of this analysis can support decisions in the future: Which customer usually needs more (or less) products than originally ordered? Which supplier delivers usually with a delay?
MAES-5	An energy manager can export data in order to re-use it in other tools (e.g. for reporting)	If MAESTRI calculates/monitors KPIs related to energy and resource efficiency, it should allow to export this data to "neutral" data formats like text/CSV files, so that users have the flexibility to re-use this KPI data in different types of reports. An example: if industrial MAESTRI users are asked by their customers to provide a report about the eco efficiency of their products in a customer-specific format, the transfer of data from MAESTRI to the reports should be as easy as possible.
MAES-6	The production manager can access a waste database in order to verify IS opportunities for a certain type of waste	The production manager is continuously looking for opportunities to improve the manufacturing processes and create values for the company. She/he identified an increased waste stream during the last periodic review of the facilities and needs to study the possibilities to eliminate or exploit that particular waste. Using a waste database will help in identifying these

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		possibilities.
MAES-7	The production manager gets a prediction of short term customer demands in order to enable an efficient production planning	To be able to optimize the production planning in terms of energy and resource efficiency, MAESTRI should support the short term forecasting of customer demands, based on data about factors that influence customer demands on a short term. As an example: the short term customer demands for paints/varnishes are influenced by the weather, e.g. in spring the people start the outdoor application of paint/varnishes depending on the weather
MAES-16	The production process designer can get information about the different production steps in order to evaluate options for process/installation changes	Based on a detailed analysis of the as-is situation in the production (e.g. runtime per process step, energy consumption per process step or per machine), the production process designer can decide if changes of the processes could improve the efficiency. Examples for possible changes: * parallelisation of process steps that currently are running in a row * changes from batch to continuous production
MAES-3	The MASTRI user can see and use data from existing systems without the need for manual data transfer	MAESTRI should read data from existing systems (e.g. Production Planning and Control systems, Enterprise Resource Planning Systems, Energy Management systems), to reduce the need for manual data insertion as far as possible. This approach will increase the user acceptance and lower the "entry barrier" for new MAESTRI users.
MAES-21	The department manager can access a management board in order to check on key performance and eco indicators	The department manager monitors the processes on a management board on the computer, with selected key performance and eco indicators exposed on it. For every indicator there is a chart with current trend vs. target available. Targets are ambitious and require improvements to be achieved. The department manager has collaborated with the production manager in defining indicators and improvement targets. The production manager understands why they are so important for the company (by using the Hoshin Kanri method). He/she made an analysis using the total efficiency platform and now knows how improvements in specific eco indicators (monitored on his management board) result in tangible benefits for the company. The management board provides not only measurements for

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		selected indicators but also a plan for improvement actions to achieve ambitious targets based on the indicator measurements, including eco indicators. Thanks to Eco A3, another tool of the total efficiency platform based on the A3 problem solving method , they know how to achieve the targets related to eco performance implementing organizational improvements.
MAES-25	Plant managers can use the Total Efficiency Platform in order to simulate the effect of higher efficiency and eco-efficiency performance	Plant managers from plant A and B, respectively, meet and analyse the results of the Total Efficiency Platform. They notice that Plants A and B, despite using identical processes, have large differences in some sectors regarding efficiency and eco-efficiency performance. Consequently, the first step is to identify for each sector which plant has better efficiency and eco-efficiency performance in that sector. After that, the plant managers simulate what their plant efficiency would be if they were to combine the best performance of each plant, i.e. consider the highest efficiency and eco-efficiency performance for each sector. Promptly they notice that they would be close to the target. Yet, both plants still have to improve material efficiency by a target percentage and optimize water and energy consumption.
MAES-27	Plant managers communicate with shift and sector supervisors in order to spread the knowledge on how to enhance efficiency and eco-efficiency performance	The plant managers define a work plan, involving their shift and sector supervisors, in order to share experiences and knowledge ("best practices" already used in each plant) on how to enhance efficiency and eco-efficiency performance. The teams from Plants A and B also work together to define improvement actions in order to improve water, energy and material consumption.
MAES-31	Plant managers can use the Total Efficiency Platform in order to create monthly reports on efficiency and eco-efficiency	Plant managers create on a monthly basis a standard report to document the efficiency and eco-efficiency performance of the respective plant to the board. Since the reports are quantitative, the board can easily evaluate if the goals are on track. The board members can evaluate the performance evolution of the relevant KPI (energy, water, material consumption and CO2 emissions) online by using the Total Efficiency Platform.
MAES-30	Plant managers can use the Total Efficiency Platform in order to select KPIs to appear on the dashboard	The plant managers redefine the Total Efficiency dashboard configuration in order to show relevant KPI evolution and deviations from the target values on the display available on the shop floor, so workers can keep track of improvements and needed

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		effort.
MAES-24	The board can use the Total Efficiency Platform in order to define sustainability targets.	Due to regulatory and cost issues as well as company strategy, the board focuses on energy (electricity, fuel and gas), water and material consumption in addition to CO2 emissions. The board and plant managers define the sustainability targets, taking into account the efficiency and eco-efficiency performance of the last period.
MAES-23	The plant manager has access to methods and tools in order to identify consumption patterns and make forecasts	The plant manager uses the methods & tools that are based on suppositional models in order to: a) Predict/identify consumption patterns and emission projections of new technology; b) Forecast energy and resources efficiency; and c) Simulate the impact of different scenarios. Such decision support models (e.g. to replace or not to replace old technology) enable the plant manager to forecast the environmental and economic impact and the overall efficiency increase. For instance, it was possible to forecast the overall effect related to the use of a different technology, and to conclude that replacing the existing technology is a must and the payback period is acceptable after that specific analysis has been performed.
MAES-22	The sector manager can access the Total Efficiency Platform in order to monitor a production line's efficiency and eco-efficiency	The sector manager has been monitoring the efficiency and eco-efficiency of a production line using the Total Efficiency Platform. He/she noticed that the system's efficiency (energy and resource consumption) and eco-efficiency performance were low. He/she also noticed that the system under analysis is the largest contributor in terms of costs, due to high running costs and low resource efficiency.
MAES-20	The plant manager can request a workshop on low-cost eco performance improvements in order to improve eco performance.	Thanks to a workshop on low-cost eco performance improvements and case studies shown during that workshop, the plant manager Andrew is convinced that improving eco performance is possible without big investments. He got to know tools that help to achieve organizational improvements resulting in decrease of energy, water and gas use as well as reduction of material scrap and emissions. During the workshop, Andrew himself has gained practical experience, since he has been involved in hands-on training in applying these tools in the host company.

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MAES-19	The waste responsible can access a guideline in order to get help on how to uncover waste sources in the company.	The waste responsible is continuously looking for opportunities to improve the manufacturing processes and create value for the company. She/he identified an increased waste stream during the last periodic review of the facilities, using a set of guidelines for "how to see waste", and has immediately requested additional data from the waste monitoring system (or waste database?) to better characterise this waste.
MAES-18	Product data can be monitored in order to determine a product's eco footprint.	There is a tendency of a product's eco footprint getting coupled with customer's buying decision. The possibility of monitoring the resource consumption of a specific production batch gives the means to determine a product's eco footprint. Resources are energy(heat and electricity), water, raw materials, auxiliary materials, cleaning liquids.
MAES-17	The production manager can simulate the fine-grain production scheduling in order to validate potential scheduling changes.	Besides the high-level production planning and scheduling which is influenced by the supply chain, also the fine-grain production scheduling is to be improved to get a better capacity utilization. A simulation system is to be used to compare a variety of scheduling possibilities.
MAES-14	The production manager is able to monitor, analyse and mine data of ecological performance indicators in order to find ecological hotspots	MAESTRI should support the detection of weak points and improvement potentials regarding energy and resource efficiency.
MAES-13	The waste responsible of a company can offer waste on a kind of "waste marketplace" in order to find potential buyers	Companies can have several types and amounts of waste, which often occurs in specific intervals. Such waste could be offered on a kind of "waste marketplace", where sellers and buyers can publish their offers and needs, respectively.
MAES-4	The production scheduler can get a simulation of production scheduling on MES level in order to be able to improve the scheduling	MAESTRI should support the simulation of production scheduling on MES level, so that users can try different options for the production scheduling and select the best option in terms of capacity utilisation, thereby improving the energy and resource efficiency.

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4.2 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.).

In the following table you can find an overview of the initial non-functional requirements:

Req-Id	Summary	Rationale	Req-Type
MAES-34	Emissions to air, water and soil must be monitored in order to find potential optimization steps.	Emissions to air, water and soil released need to be monitored and quantified in order to understand which emissions and which quantities are released into the air and/or water.	Non-Functional - operational
MAES-29	Relationship between process variables and material properties need to be understood in order to support individualization of products to customer needs.	Due to high demand of customers for more individualization of products the need for the production company arises to use new materials. There is a gap of knowledge how new materials need to be processed in order to meet the quality and throughput levels required to fulfil the orders and to adjust the process variables accordingly.	Non-Functional - operational
MAES-33	Water consumption must be monitored based on the process steps in order to find potential optimization steps.	Water consumed and/or generated of all processes and each stage need to be monitored in order to analyse where value is added or not.	Non-Functional - operational
MAES-8	Changes to process parameters need to be performed quickly in order to test out new parameter sets for production processes	New projects (very often) demand that trials are to be made in the production processes to adjust process parameters.	Non-Functional - performance
MAES-11	Access to forecasting data needs to be included in production planning in order to meet delivery deadlines.	Forecast data needs to be made available to production planning so that the production plans can include safety buffer if some breakdown happens and delivery time can still be met.	Non-Functional - operational
MAES-9	Downtimes of machines need to be recorded and analysed in order to optimize the machine-availability	In order to increase the availability of machines the relevant process parameters need to be monitored so that an analysis can be run in case a machine breaks down.	Non-Functional - operational
MAES-10	Relevant set of KPIs needs to be defined in order to maximize the	It needs to be identified which set of KPIs increases the reliability of providing the exact status of the	Non-Functional - operational

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	impact	operation and allows to identify concrete optimization potential.	
MAES-26	Existing suite of applications needs to better integrated in order to make them easier to use	Human Machine Interfaces and the existing suite of integrated applications at different levels of the process systems are not integrated well enough so the efficiency is reduced due to different production environments in different sites.	Non-Functional - usability
MAES-32	Energy consumption must be monitored based on the process steps in order to find potential optimization steps.	Process energy and pre-combustion energy consumed and /or generated of all processes and each stage need to be monitored in order to analyse where value is added or not.	Non-Functional - operational

5 Conclusion

So far we have collected 34 requirements and this is a solid foundation for the work ahead and further discussions in order to add new and refine the existing requirements. The next steps will be to discuss which requirements to include in the specification and start working on the architecture for the MAESTRI platform (WP 5) and continue the work in the work packages for the three pillars of MAESTRI namely WP 2 Efficiency Framework, WP 3 Management System and WP 4 Industrial Symbiosis.

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6 Appendix A - Complete Requirements from JIRA

Here you can find the complete list of the initial requirements:

Key	Summary	Rationale	Fit Criterion	Customer Satisfaction	Customer Dissatisfaction	Requirement Type
MAES-1	The platform will store the monitoring data permanently in order to access it later	For the optimization of processes one needs to analyse historic data to identify wasteful activities and develop effective counter-measurements. The data should include timestamps in order to retrieve data based on a specific timeframe.	Monitoring data will be stored permanently and it can be retrieved by a specific API.	neutral	very high	Functional
MAES-12	The production manager is able to identify the most valuable use of scrap parts in order to maximize the revenue.	Even if a company is already selling waste and scrap parts they probably do not know all of the alternatives how this could be monetized and could do so with such a functionality in a much more effective way.	The production manager is able to find a list of potential industrial symbiosis activities for a specific material together with the estimated amount of revenue.	very high	high	Functional
MAES-34	Emissions to air, water and soil must be monitored in order to find potential optimization steps.	Emissions to air, water and soil released need to be monitored and quantified in order to understand which emissions and which quantities are released into the air and/or water.	Emissions to air, water and soil released are monitored and quantified	very high	high	Non-Functional - operational
MAES-29	Relationship between process variables and material properties need to be understood in order to support individualization of products to customer needs.	Due to high demand of customers for more individualization of products the need for the production company arises to use new materials. There is a gap of knowledge how new materials need to be processed in order to meet the quality and throughput levels required to fulfil the orders and to adjust the process variables accordingly.	For 80% of the process variables used in the production process it is known how changes to material properties would influence the output qualities.	very high	high	Non-Functional - operational
MAES-28	Reorder amount of	Calculating the reorder amount for raw material is	Calculating the reorder	very high	high	Functional

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	raw material needs to be calculated automatically in order to reduce miscalculations	not automated so users use Excel and the result depends on the experience of the user with the processes involved.	amount of raw material can be automated and the algorithm can be specified to match the company´s need.			
MAES-33	Water consumption must be monitored based on the process steps in order to find potential optimization steps.	Water consumed and/or generated of all processes and each stage need to be monitored in order to analyse where value is added or not.	Water consumed and/or generated is monitored for all process stages in the processes under investigation.	high	neutral	Non-Functional - operational
MAES-2	The system administrator can specify the time interval for monitoring the data in order to reduce the amount of data to be processed.	The system administrator of the MAESTRI platform can specify a time interval for each of the sensors that will be monitored in order to reduce the amount of data that will be processed within the platform. Temperature sensors monitoring e.g. the room temperature need to monitored in longer intervals (like every 5 minutes) compared to temperature of a plastic injection machine where we want to analyse the temperature curve of one cycle time and this needs to be done in a much shorter interval (like every 500ms).	For every sensor the system administrator can specify the time interval for the measurement.	neutral	high	Functional
MAES-8	Changes to process parameters need to be performed quickly in order to test out new parameter sets for production processes	New projects (very often) demand that trials are to be made in the production processes to adjust process parameters.	The prototyping time for process parameter changes will be reduced by 10% for the processes related to the MAESTRI project.	very high	neutral	Non-Functional - performance
MAES-11	Access to forecasting data needs to be included in production planning in order to meet delivery deadlines.	Forecast data needs to be made available to production planning so that the production plans can include safety buffer if some breakdown happens and delivery time can still be met.	Forecast data is accessible to the production planner either based on data coming from external sources or it is derived	very high	high	Non-Functional - operational

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			based on the analysis of the historic production data of the processes.			
MAES-9	Downtimes of machines need to be recorded and analysed in order to optimize the machine-availability	In order to increase the availability of machines the relevant process parameters need to be monitored so that an analysis can be run in case a machine breaks down.	The relevant monitoring data and frequency of each machine has been documented and the data is collected and stored accordingly.	very high	high	Non-Functional - operational
MAES-10	Relevant set of KPIs needs to be defined in order to maximize the impact	It needs to be identified which set of KPIs increases the reliability of providing the exact status of the operation and allows to identify concrete optimization potential.	For each process a set of KPIs has been identified and documented that allows proper monitoring of the company processes.	very high	high	Non-Functional - operational
MAES-15	The supply chain manager is able to analyse historical data about problems the supply chain in order to get decision support for future planning	The supply chain manager is able to identify reasons for disturbances in production planning caused by supply chain events based on the analysis of historical data (comparison of plan data and actual data). Results of this analysis can support decisions in the future: Which customer usually needs more (or less) products than originally ordered? Which supplier delivers usually with a delay?	Relevant historical data related to the supply-chain are collected. Historical plan and historical actual data will be compared and analysed for deviations. Statistical deviations are presented to the user.	high	high	Functional
MAES-5	An energy manager can export data in order to re-use it in other tools (e.g. for reporting)	If MAESTRI calculates/monitors KPIs related to energy and resource efficiency, it should allow to export this data to "neutral" data formats like text/CSV files, so that users have the flexibility to re-use this KPI data in different types of reports. An example: if industrial MAESTRI users are asked by their customers to provide a report about the eco efficiency of their products in a customer-specific format, the transfer of data from MAESTRI to the reports should be as easy as possible.	MAESTRI provides an export function for calculated/monitored KPIs to text/CSV files.	high	neutral	Functional

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MAES-6	The production manager can access a waste database in order to verify IS opportunities for a certain type of waste	The production manager is continuously looking for opportunities to improve the manufacturing processes and create values for the company. She/he identified an increased waste stream during the last periodic review of the facilities and needs to study the possibilities to eliminate or exploit that particular waste. Using a waste database will help in identifying these possibilities.	For each waste type of a given set of waste types, there is an entry in the waste database providing the industrial symbiosis opportunities for these waste types.	neutral	very high	Functional
MAES-7	The production manager gets a prediction of short term customer demands in order to enable an efficient production planning	To be able to optimize the production planning in terms of energy and resource efficiency, MAESTRI should support the short term forecasting of customer demands, based on data about factors that influence customer demands on a short term. As an example: the short term customer demands for paints/varnishes are influenced by the weather, e.g. in spring the people start the outdoor application of paint/varnishes depending on the weather	A forecast of the expected customer demands for different types of products in the short term is displayed.	high	neutral	Functional
MAES-16	The production process designer can get information about the different production steps in order to evaluate options for process/installation changes	Based on a detailed analysis of the as-is situation in the production (e.g. runtime per process step, energy consumption per process step or per machine), the production process designer can decide if changes of the processes could improve the efficiency. Examples for possible changes: * parallelisation of process steps that currently are running in a row * changes from batch to continuous production	The production process designer gets enough information about the current situation in order to estimate the possible success of process/installation changes and enable a calculation of the expected payback period of the investment	high	high	Functional
MAES-3	The MASTRI user can see and use data from existing systems without the need for manual data transfer	MAESTRI should read data from existing systems (e.g. Production Planning and Control systems, Enterprise Resource Planning Systems, Energy Management systems), to reduce the need for manual data insertion as far as possible. This approach will increase the user acceptance	Users do not have to insert any data into MAESTRI that is already existing in other systems in the company.	neutral	high	Functional

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		and lower the "entry barrier" for new MAESTRI users.				
MAES-26	Existing suite of applications needs to better integrated in order to make them easier to use	Human Machine Interfaces and the existing suite of integrated applications at different levels of the process systems are not integrated well enough so the efficiency is reduced due to different production environments in different sites.	80% of the functionality of the process systems functions are integrated in a unified Human Machine Interface (HMI).	very high	neutral	Non-Functional - usability
MAES-32	Energy consumption must be monitored based on the process steps in order to find potential optimization steps.	Process energy and pre-combustion energy consumed and /or generated of all processes and each stage need to be monitored in order to analyse where value is added or not.	Process energy and pre-combustion energy consumed and/or generated is monitored for all process stages in the processes under investigation.	very high	very high	Non-Functional - operational
MAES-21	The department manager can access a management board in order to check on key performance and eco indicators	The department manager monitors the processes on a management board on the computer, with selected key performance and eco indicators exposed on it. For every indicator there is a chart with current trend vs. target available. Targets are ambitious and require improvements to be achieved. The department manager has collaborated with the production manager in defining indicators and improvement targets. The production manager understands why they are so important for the company (by using the Hoshin Kanri method). He/she made an analysis using the total efficiency platform and now knows how improvements in specific eco indicators (monitored on his management board) result in tangible benefits for the company. The management board provides not only measurements for selected indicators but also a plan for improvement actions to achieve ambitious targets based on the indicator measurements, including eco indicators. Thanks to Eco A3, another tool of the total efficiency	The user can access a management board and check for a given set of KPIs and eco indicators: values, chart with current trend vs. target value.	neutral	high	Functional

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		platform based on the A3 problem solving method , they know how to achieve the targets related to eco performance implementing organizational improvements.				
MAES-25	Plant managers can use the Total Efficiency Platform in order to simulate the effect of higher efficiency and eco-efficiency performance	Plant managers from plant A and B, respectively, meet and analyse the results of the Total Efficiency Platform. They notice that Plants A and B, despite using identical processes, have large differences in some sectors regarding efficiency and eco-efficiency performance. Consequently, the first step is to identify for each sector which plant has better efficiency and eco-efficiency performance in that sector. After that, the plant managers simulate what their plant efficiency would be if they were to combine the best performance of each plant, i.e. consider the highest efficiency and eco-efficiency performance for each sector. Promptly they notice that they would be close to the target. Yet, both plants still have to improve material efficiency by a target percentage and optimize water and energy consumption.	Plant managers can simulate the effect of a higher efficiency and eco-efficiency performance on their plant through the Total Efficiency Platform.	neutral	high	Functional
MAES-27	Plant managers communicate with shift and sector supervisors in order to spread the knowledge on how to enhance efficiency and eco-efficiency performance	The plant managers define a work plan, involving their shift and sector supervisors, in order to share experiences and knowledge ("best practices" already used in each plant) on how to enhance efficiency and eco-efficiency performance. The teams from Plants A and B also work together to define improvement actions in order to improve water, energy and material consumption.	Plant managers organize 6 workshops per year to communicate best practices on how to enhance efficiency and eco-efficiency performance.	neutral	high	Functional
MAES-31	Plant managers can use the Total Efficiency Platform in order to create monthly reports on efficiency and eco-	Plant managers create on a monthly basis a standard report to document the efficiency and eco-efficiency performance of the respective plant to the board. Since the reports are quantitative, the board can easily evaluate if the goals are on track. The board members can	The user can create on a monthly basis a standard report to document the efficiency and eco-efficiency performance	neutral	high	Functional

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	efficiency	evaluate the performance evolution of the relevant KPI (energy, water, material consumption and CO2 emissions) online by using the Total Efficiency Platform.	of the respective plant.			
MAES-30	Plant managers can use the Total Efficiency Platform in order to select KPIs to appear on the dashboard	The plant managers redefine the Total Efficiency dashboard configuration in order to show relevant KPI evolution and deviations from the target values on the display available on the shop floor, so workers can keep track of improvements and needed effort.	The user selects a given set of KPIs using the Total Efficiency Platform and have them displayed on the Total Efficiency dashboard on the shop floor: KPI evolution and deviation from the target values.	neutral	high	Functional
MAES-24	The board can use the Total Efficiency Platform in order to define sustainability targets.	Due to regulatory and cost issues as well as company strategy, the board focuses on energy (electricity, fuel and gas), water and material consumption in addition to CO2 emissions. The board and plant managers define the sustainability targets, taking into account the efficiency and eco-efficiency performance of the last period.	The user can define sustainability targets using the Total Efficiency Platform.	neutral	high	Functional
MAES-23	The plant manager has access to methods and tools in order to identify consumption patterns and make forecasts	The plant manager uses the methods & tools that are based on suppositional models in order to: a) Predict/identify consumption patterns and emission projections of new technology; b) Forecast energy and resources efficiency; and c) Simulate the impact of different scenarios. Such decision support models (e.g. to replace or not to replace old technology) enable the plant manager to forecast the environmental and economic impact and the overall efficiency increase. For instance, it was possible to forecast the overall effect related to the use of a different technology, and to conclude that replacing the existing technology is a must and the payback period is acceptable after that specific analysis	Methods and tools for consumption patterns identification as well as for energy and resources efficiency forecasting are available.	neutral	high	Functional

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		has been performed.				
MAES-22	The sector manager can access the Total Efficiency Platform in order to monitor a production line's efficiency and eco-efficiency	The sector manager has been monitoring the efficiency and eco-efficiency of a production line using the Total Efficiency Platform. He/she noticed that the system's efficiency (energy and resource consumption) and eco-efficiency performance were low. He/she also noticed that the system under analysis is the largest contributor in terms of costs, due to high running costs and low resource efficiency.	The Total Efficiency Platform is available and can be used to monitor a production line's efficiency and eco-efficiency.	neutral	high	Functional
MAES-20	The plant manager can request a workshop on low-cost eco performance improvements in order to improve eco performance.	Thanks to a workshop on low-cost eco performance improvements and case studies shown during that workshop, the plant manager Andrew is convinced that improving eco performance is possible without big investments. He got to know tools that help to achieve organizational improvements resulting in decrease of energy, water and gas use as well as reduction of material scrap and emissions. During the workshop, Andrew himself has gained practical experience, since he has been involved in hands-on training in applying these tools in the host company.	Plant manager can request to attend a workshop on low-cost eco performance improvements. The workshop material is available.	neutral	high	Functional
MAES-19	The waste responsible can access a guideline in order to get help on how to uncover waste sources in the company.	The waste responsible is continuously looking for opportunities to improve the manufacturing processes and create value for the company. She/he identified an increased waste stream during the last periodic review of the facilities, using a set of guidelines for "how to see waste", and has immediately requested additional data from the waste monitoring system (or waste database?) to better characterise this waste.	The user can access a "how to see waste" guideline and get help on how to uncover waste sources in the company.	neutral	high	Functional
MAES-18	Product data can be monitored in order to determine a product's eco footprint.	There is a tendency of a product's eco footprint getting coupled with customer's buying decision. The possibility of monitoring the resource consumption of a specific production batch gives the means to determine a product's eco footprint.	The eco footprint of each product belonging to a given set of products can be determined.	neutral	high	Functional

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		Resources are energy(heat and electricity), water, raw materials, auxiliary materials, cleaning liquids.				
MAES-17	The production manager can simulate the fine-grain production scheduling in order to validate potential scheduling changes.	Besides the high-level production planning and scheduling which is influenced by the supply chain, also the fine-grain production scheduling is to be improved to get a better capacity utilization. A simulation system is to be used to compare a variety of scheduling possibilities.	There is a simulation system through which a variety of production scheduling possibilities can be compared concerning their production capacity utilization figures. The higher capacity utilization can be determined using the simulation system.	neutral	high	Functional
MAES-14	The production manager is able to monitor, analyse and mine data of ecological performance indicators in order to find ecological hotspots	MAESTRI should support the detection of weak points and improvement potentials regarding energy and resource efficiency.	MAESTRI is able to monitor eco-efficiency related data sources (databases, sensors, etc.). MAESTRI is able to analyse monitored data to identify hotspots of energy consumption and waste generation. MAESTRI presents the weak points to the production manager as potential issues for improvement.	high	high	Functional
MAES-13	The waste responsible of a company can offer waste on a kind of "waste marketplace" in order	Companies can have several types and amounts of waste, which often occurs in specific intervals. Such waste could be offered on a kind of "waste marketplace", where sellers and buyers can	A waste manager is able to insert detailed information about the company's waste.	high	neutral	Functional

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	to find potential buyers	publish their offers and needs, respectively.	A potential customer is able to insert detailed information about the company's "need for waste". MAESTRI informs waste managers about potential customers based on automatic matching between offers and requests.			
MAES-4	The production scheduler can get a simulation of production scheduling on MES level in order to be able to improve the scheduling	MAESTRI should support the simulation of production scheduling on MES level, so that users can try different options for the production scheduling and select the best option in terms of capacity utilisation, thereby improving the energy and resource efficiency.	Users can change scheduling parameters and see a simulation of the expected consequences of the adapted scheduling.	very high	neutral	Functional

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