

Project ID <b>284860</b>	MSEE – Manufacturing Services Ecosystem	
Date: <b>30/03/2012</b>	D51.2 – Methodology for requirement engineering and evaluation in MSEE	



*D51.2 –  
Methodology for  
Requirements Engineering & Evaluation in  
Manufacturing Service Ecosystems – M6*

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Dissemination:	Public
Contributing to:	WP 51
Date:	30/04/2012
Revision:	1.0

NO.	DATE	NOTES AND COMMENTS
0.1	24/02/2012	DELIVERABLE STRUCTURE AND TOC
0.2	02/03/2012	INITIAL DOCUMENT WITH INTRODUCTION, CHAPTER 4 DRAFT
0.3	06/03/2012	SERVICE MODELING ADDED FOR CHAPTER 2
0.4	09/03/2012	SP1 INPUT FOR CHAPTER 3
0.5	11/03/2012	CHAPTER 2
0.6	16/03/2012	CHAPTER 3
0.7	23/03/2012	SUMMARY & CONCLUSIONS
0.8	30/03/2012	CORRECTED AND EXTENDED VERSION FOR INTERNAL REVIEW
1.0	30/04/2012	FINAL VERSION AFTER INTERNAL REVIEW

#### DELIVERABLE PEER REVIEW SUMMARY

ID	Comments	Addressed (✓) Answered (A)
1	Can the requirements engineering methodology (as a procedure to be used in MSEE) become a generalised methodology for MSEs?	The methodology developed in T51.2 is in principle generic but aligned with the specific needs of the MSEE project. Therefore it can be used as a generalised methodology for MSEs by adapting the single steps to the characteristics of the individual MSE. This is made clearer in the text.
2		

TABLE OF CONTENTS

<b>EXECUTIVE SUMMARY</b>	<b>5</b>
<b>1. INTRODUCTION</b>	<b>6</b>
1.1. <i>Objective of the Deliverable</i>	7
1.2. <i>Structure of the Deliverable</i>	8
<b>2. METHODOLOGY FOR REQUIREMENTS ENGINEERING</b>	<b>9</b>
2.1. <i>Existing Requirements Engineering Methodologies</i>	10
2.2. <i>Implications for Requirements Engineering in Manufacturing Service Ecosystems</i>	13
2.3. <i>Requirements Elicitation</i>	20
2.4. <i>Requirements Analysis</i>	24
2.5. <i>Requirements Documentation and Specification</i>	25
2.6. <i>Requirements Validation</i>	29
<b>3. PERFORMANCE INDICATORS FOR MANUFACTURING SERVICE ECOSYSTEMS</b>	<b>32</b>
3.1. <i>The ECOGRAI Method for Performance Indicator Systems</i>	33
3.2. <i>Performance Indicators for Servitization</i>	35
3.3. <i>Performance Indicators for Ecosystem Governance</i>	37
3.4. <i>Performance Indicators for Service Innovation</i>	39
<b>4. METHODOLOGY FOR BUSINESS EVALUATION</b>	<b>40</b>
4.1. <i>Assessment of the MSEE Impact on Process Performance</i>	40
4.2. <i>The Value Reference Model Framework</i>	41
4.3. <i>Selection and Measurement of Metrics for the MSEE End-Users</i>	44
<b>5. SUMMARY AND CONCLUSIONS</b>	<b>45</b>
<b>6. REFERENCES</b>	<b>46</b>

## LIST OF FIGURES

Figure 1: Requirements Engineering in MSEE	6
Figure 2: Structure of D51.2	8
Figure 3: Cost for changing Requirements in the beginning of the Product Life-Cycle [Wiesner, Steinberg & Seifert 2011], according to [Woll 1996]	9
Figure 4: Basic Steps of Requirements Engineering, after [Schienmann 2002]	10
Figure 5: Traditional Systems Analysis [Haumer et al. 1998]	11
Figure 6: Parallel Requirements Engineering as a Phase	12
Figure 7: Phase-Independent Requirements Engineering	14
Figure 8: Cross-Project Requirements Engineering	14
Figure 9: Continuous Cross-Pilot Requirements Engineering in MSEE	15
Figure 10: Approach for Serious Games in Requirements Engineering and the associated MSEE Work Packages.	17
Figure 11: Serious Gaming approach in MSEE	18
Figure 12: Schedule for Requirements Elicitation through Serious Games in MSEE	19
Figure 13: Overview of a generic Collaboration Scenario	22
Figure 14: The refQuest Gaming User Interface in a Web Browser	23
Figure 15: The refQuest Process for Requirements Specification	24
Figure 16. System Lifecycle and Modelling Levels	28
Figure 17. Modeling constructs and relationships at BOM level	28
Figure 18: Inputs and Outputs of the RE Activities	31
Figure 19: Principle of Performance Measurement in MSEE	32
Figure 20: Implementation of KPI Framework in MSEE	33
Figure 21: The six Phases of ECOGRAI [MSEE D11.1]	34
Figure 22: ECOGRAI Implementation Groups [MSEE D11.1]	35
Figure 23: Performance Indicators in MDSE Levels [MSEE D11.1]	36
Figure 24: Downward Decision Flow between UGF Layers [D13.1]	38
Figure 25: Upward Information Flow between UGF Layers [D13.1]	38
Figure 26: Classification of Innovation Indicators [D13.1]	39
Figure 27: Ecosystem Benefits generated by Process Improvements	40
Figure 28: VRM Strategic and Tactical Level Processes [VCG 2012]	42
Figure 29: VRM Operational Level Processes [VCG 2012]	42

## LIST OF TABLES

Table 1: Requirements List Example	27
Table 2: Template for Service Description	29
Table 3: VRM Priority Dimensions [VCG 2012]	43
Table 4: VRM Metric Information	43

## Executive Summary

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This deliverable is part of MSEE WP51 “Methodology for Requirements Engineering & Evaluation”. It is the second deliverable of the work package, due at month 6, and will define a novel concept for Requirements Engineering & Evaluation in Manufacturing Service Ecosystems. According to the DoW, D51.2 “Methodology for Requirements Engineering & Evaluation in Manufacturing Service Ecosystems” has the following content:

*“Based on the results of T51.1, a novel concept will be defined for a methodology to generate user requirements for Virtual Factories & Enterprises in Manufacturing Service Ecosystems and measure their fulfilment. It is planned to develop the methodology on pre-defined measurable indicators in several dimensions, featuring the preferential goals and objectives in a Business Ecosystem context. For each member of the ecosystem, internal tactical and operational priorities can be developed. This allows selecting the appropriate KPIs, metrics and criteria to evaluate the tactical and operational improvements of implementing the MSEE system.”<sup>1</sup>*

In the deliverable, the above content has been organized in five distinct chapters, developing the methodology for Requirements Engineering (RE), describing possible performance indicators for Manufacturing Service Ecosystems and including them into the methodology for MSEE business evaluation. The structure of chapters is listed below:

- Chapter 1: Introduction to the topic, objectives and structure of the deliverable.
- Chapter 2: Methodology for Requirements Engineering.
- Chapter 3: Performance Indicators for Manufacturing Service Ecosystems.
- Chapter 4: Methodology for Business Evaluation.
- Chapter 5: Summary and Conclusions for the project.

Requirements Engineering in MSEE is conducted continuously in an iterative approach and is organized in two successive phases, according to the overall two-spiral approach of the project. In the first phase, existing approaches from the state-of-the-art in requirements elicitation have been selected according to their applicability in the project. Guided questionnaires and a Requirements Workshop with Focus Groups and Brainstorming sessions have been used to deliver an early set of preliminary requirements.

In this document, the methodology for Requirements Engineering and business evaluation which will be used for the second phase is described. It will be used to refine the requirements generated in phase one (see D52.1) and to maximize the impact of the MSEE results. As the end-user is not really aware of his/her needs in a complex environment like a Manufacturing Service Ecosystem, the methodology is based on new innovative approaches for requirements elicitation, analyses, specification and evaluation. The methods which are therefore explored include Serious Gaming, Service Modeling and the Value Reference Model.

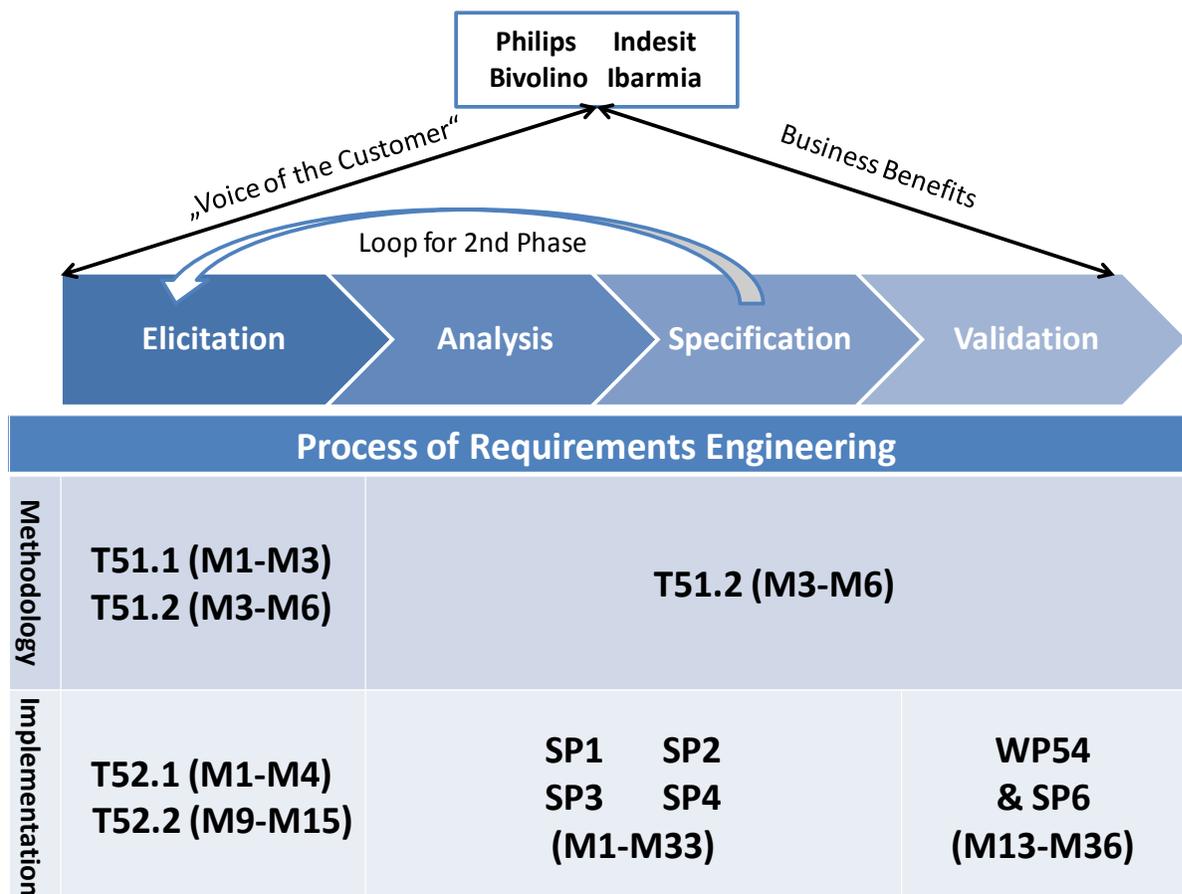
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<sup>1</sup> MSEE Description of Work – T51.2 section

## 1. Introduction

This deliverable presents the new methodology for Requirements Engineering and Business Evaluation in MSEE, which has been developed based on the results presented in the previous deliverable D51.1. The analysis of existing requirements elicitation approaches has shown gaps to deliver a set of detailed requirements in the scope of MSEE. The elicitation of requirements for complex solutions in an ecosystem environment needs a new approach, guiding the end-user through the iterative identification and detailing of requirements. The approach is put into the context of a new methodology, covering all aspects of Requirements Engineering and the evaluation of business benefits for the MSEE end-users.

The content is part of work package (WP) 51 “Methodology for Requirements Engineering & Evaluation” which belongs to the internal sub project (SP) “User Requirements, Assessment and Validation”. The results of WP51 are providing the theoretical foundation for the elicitation, analysis, specification and validation of requirements in the course of MSEE. Figure 1 shows the process of Requirements Engineering in relation to the various involved subprojects and work packages:



**Figure 1: Requirements Engineering in MSEE**

In MSEE, a continuous approach for Requirements Engineering is applied. The process is based on two successive phases, each with a specifically adapted methodology. Phase one has already started at the beginning of the project and has the main task to verify, update and detail the end-user scenario. The approach for *Requirements Elicitation* (step 1) during the first phase has been selected in T51.1 and is depicted D51.1, while the methodology for the second round of elicitation has been developed in T51.2 as well as for *Requirements Analysis* (step 2), *Specification* (step 3) and *Validation* (step 4) and is depicted in this deliverable.

Preliminary requirements of the MSEE end-users have been taken up in T52.1 as “Voice of the Customer”. SPs 1-2-3 analyze the requirements and proceed with detailed specifications, first models and software prototypes to be integrated then in SP4 platforms. For the second phase, the results of the specification are constantly fed back in a loop to another round of requirements elicitation conducted in T52.2. Using approaches like Serious Gaming or Service Modeling, the end-users will refine their requirements based on the first models and prototypes. The outcome will be re-analyzed and transformed into a revised specification for SPs 1-2-3 developments and SP4 platforms integration & testing. At the end, the business validity of the final models and the MSEE integrated system will be verified in WP54 based on the fulfillment of the user requirements and business expectations. The end-user test cases implemented in SP6 will be the field test to measure and collect the achieved business benefits.

### **1.1. Objective of the Deliverable**

According to the Description of Work (DoW), the main objectives of WP51 are:

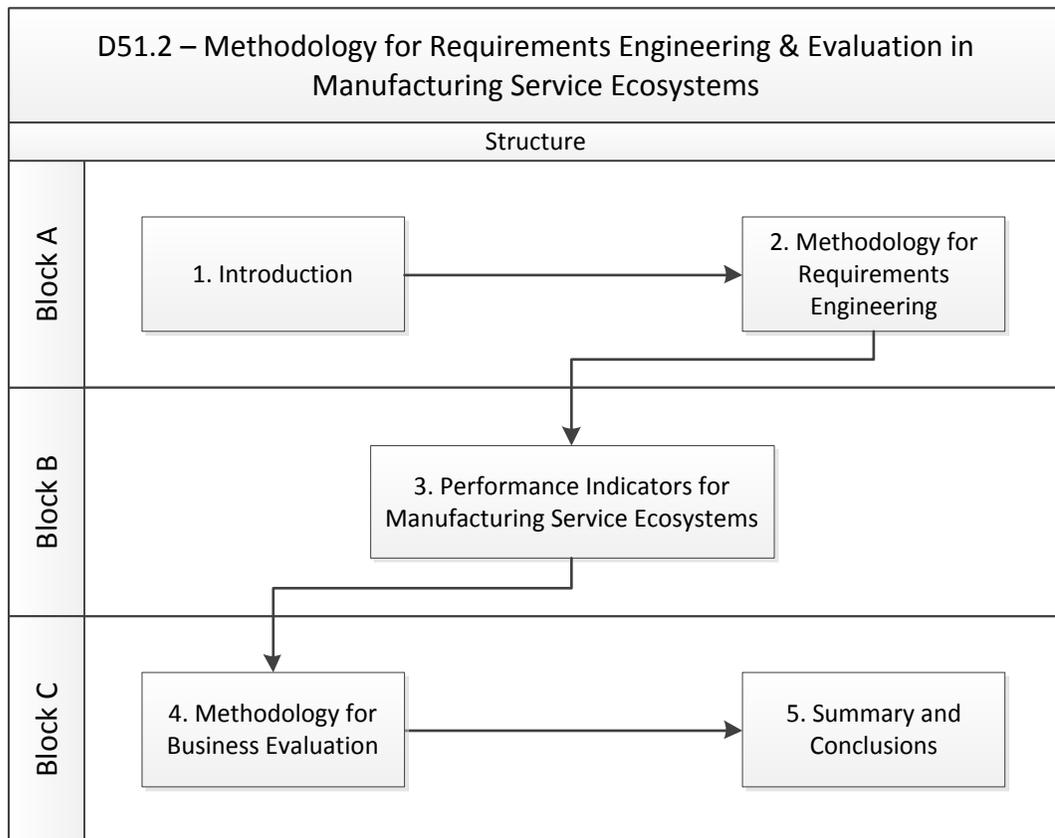
- To analyze the applicability of existing requirements elicitation approaches in Manufacturing Service Ecosystems.
- To define specific requirements engineering and evaluation methodology for Virtual Factories & Enterprises in Manufacturing Service Ecosystems.

D51.2 will contain the specific Requirements Engineering and Evaluation methodology for Virtual Factories & Enterprises in Manufacturing Service Ecosystems. Therefore, the following objectives have been determined for the deliverable:

- Development of the Requirements Engineering methodology for Manufacturing Service Ecosystems, including requirements elicitation, analysis, specification and validation in MSEE.
- Summary of the performance indicator framework for Manufacturing Service Ecosystems from WP13.
- Description of the methodology for business evaluation in Manufacturing Service Ecosystems, assessing the impact on process performance and application of the Value Reference Model for selection of indicators for the different end-user scenarios.

## 1.2. Structure of the Deliverable

The structure of the deliverable is grouped into three major blocks, according to the objectives described in section 1.1 (see Figure 2):



**Figure 2: Structure of D51.2**

**Block A** has the function to introduce the Requirements Engineering methodology and integrate the topic into the project context. Taking into account the innovative nature of the project and the characteristics of complex solutions in an ecosystem context, the process of Requirements Engineering is presented. It consists of chapters 1 and 2 and presents the methodology for Requirements Engineering in the scientific context.

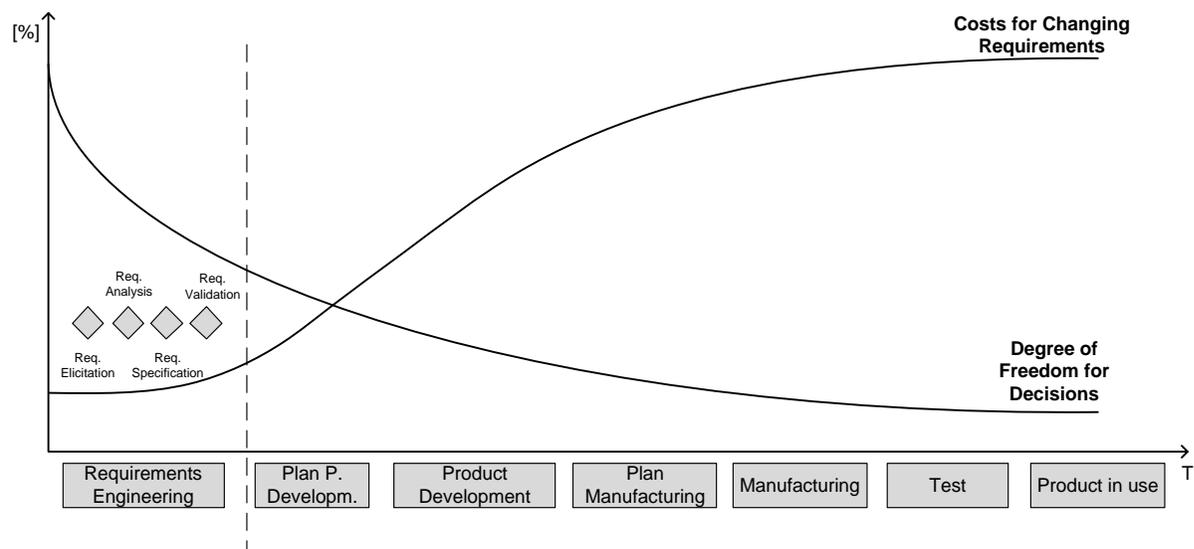
**Block B** introduces the performance indicator framework from MSEE WP13. Existing KPI approaches from various domains are described as basis for a comprehensive set of indicators featuring ecosystem goals and individual enterprise priorities. Chapter 3 lays the foundation for the evaluation of business benefits through suitable KPI's.

**Block C** contains the methodology for business evaluation, based on the indicators from Block B. Consisting of chapters 4 and 5, it describes the assessment of the MSEE impact on process performance using the Value Reference Model (VRM) framework. The process to select suitable KPI's for the different end-user scenarios is defined. Finally, the results are summarized and conclusions for further actions in the project are given.

## 2. Methodology for Requirements Engineering

Requirements Engineering describes *a process, in which the needs of one or many stakeholders and their environment are determined to find the solution for a specific problem* [Nuseibeh & Easterbrook 2000]. A thorough execution of this process is essential for the successful development of complex solutions, such as the ones which will be typically provided by Manufacturing Service Ecosystems. Inadequate Requirements Engineering is one of the most important factors for the failure of development projects. This includes exceeding budgets, missing functionalities or even the abortion of the project.

However, the importance of Requirements Engineering is often underrated, which leads to errors in requirements specification. Requirements are overlooked or are expressed unclear and incomplete. Errors in requirements specification are most often only discovered in later development phases. At the same time, costs to correct the errors will be all the higher, the later the errors are discovered (see Figure 3).



**Figure 3: Cost for changing Requirements in the beginning of the Product Life-Cycle** [Wiesner, Steinberg & Seifert 2011], according to [Woll 1996]

The correction of errors in requirements specification discovered during product development can be 20 times more expensive than during Requirements Engineering. Errors discovered during testing can be even 100 times as costly to correct [Boehm & Basili 2001]. It is therefore important to discover and correct erroneous requirements as early as possible in the Product Life-Cycle. However, Requirements Engineering is nowadays facing a number of challenges, which have to be overcome [Pohl 2008]:

- Increasing Complexity:**  
 A growing number of functionalities demanded from a solution, cross-linking and integration of systems as well as the quantity of individual customer variants increase the complexity of the solution and require a systematic development approach.
- Rising Cost Pressure:**  
 Growing competition and falling prices for a product lead to cost pressure. As a consequence, also the development costs have to be reduced.
- Shorter Development Times:**  
 Competition also demands for faster implementation of customer wishes and to have

innovative products available on the market more quickly. Thus, development times have to be reduced in spite of increasing complexity.

- **Service-based Innovation:**

Innovative properties of a solution are nowadays pre-dominantly realized through services or even only possible through servitization. Services move more and more into the center of product development and become an essential success factor.

- **Growing Quality Demands:**

Demands on the quality of a solution and its availability are constantly growing. The solution has to be offered in higher quality, notwithstanding shorter development times and high cost pressure.

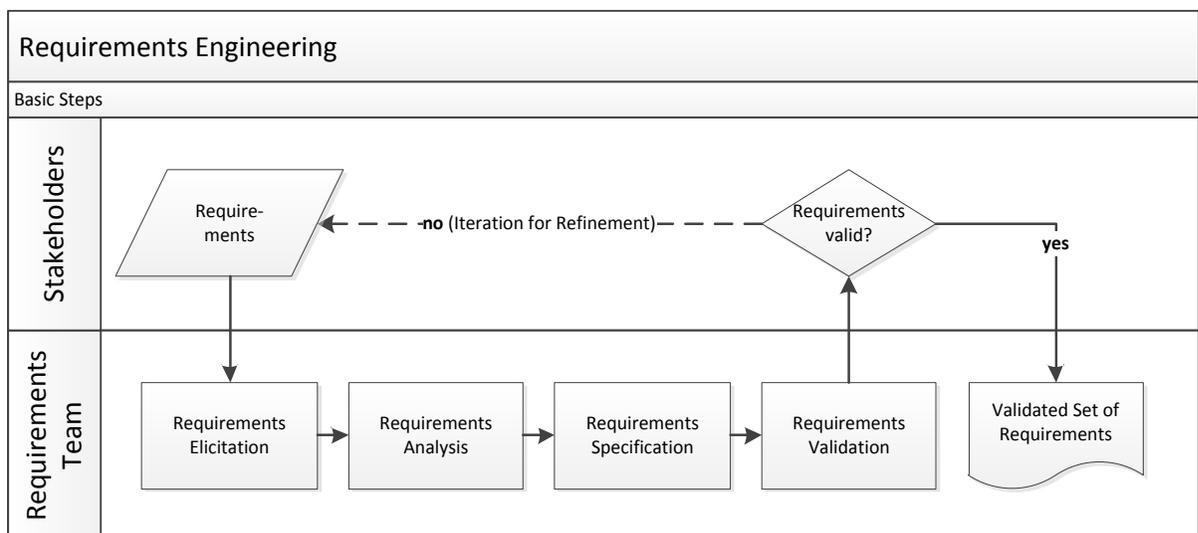
In consequence, the above challenges demand more innovative, customized and complex solutions have to be made available on the market more quickly with higher quality and falling prices. The methodology for Requirements Engineering in Manufacturing Service Ecosystems has to deal with the identified challenges in particular, as the targeted solution has to be:

1. Applicable in the context of a Business Ecosystem
2. Achievable within a limited project budget
3. Developed within the fixed project duration
4. Supporting the servitization of manufacturing
5. Satisfying the quality demands of very different and ambitious end-users

In the following section, existing approaches for requirements collection and specification will be presented and analyzed for their applicability according to the challenges mentioned above.

## 2.1. Existing Requirements Engineering Methodologies

This section will examine traditional approaches to be used for the basic steps of Requirements Engineering as described in D51.1 (see Figure 4). It describes the application of structured analysis, Systems Analysis and Requirements Engineering as a phase for the elicitation, analysis, specification and validation of requirements.



**Figure 4: Basic Steps of Requirements Engineering, after [Schienmann 2002]**

### 2.1.1. Systems Analysis

The term Systems Analysis describes different approaches to define requirements towards a system to be developed on the basis of the analysis of an existing system. As such, Systems Analysis is mainly used to support the execution of processes through incremental improvements to the existing system.

#### Structured Analysis

In traditional Systems Analysis, the functionality of a system is described in the three complementary perspectives data, functions and behavior. To model the three perspectives, languages such as data flow models, entity-relationship-models or behavioral models are used.

A well known Systems Analysis approach is the structured analysis according to DeMarco [1978], which uses data flow diagrams to document system functionalities. On the basis of the analysis of existing processes, the AS-IS situation of a system is modeled. Coming from the “AS-IS model”, the required changes are defined and the “TO-BE model” is developed. The TO-BE model specifies the requirements towards the new system (solution) to be implemented. The two different models are the result of two kinds of analysis (see Figure 5):

- **AS-IS analysis:** Facts about existing processes are collected and documented in the AS-IS models. These models thus represent the current situation of a system. The AS-IS analysis ensures the incorporation of requirements that are already implemented in the existing system and processes, known to the stakeholders or documented in e.g. error reports. Furthermore, important context information is generated, which is important for the implementation of the solution, such as interface descriptions.
- **TO-BE analysis:** Possible improvements are identified and the TO-BE model is created. Identification of improvements is based on the AS-IS model, which is accordingly modified. The resulting TO-BE model specifies the requirements towards the planned system and creates the basis for its development.

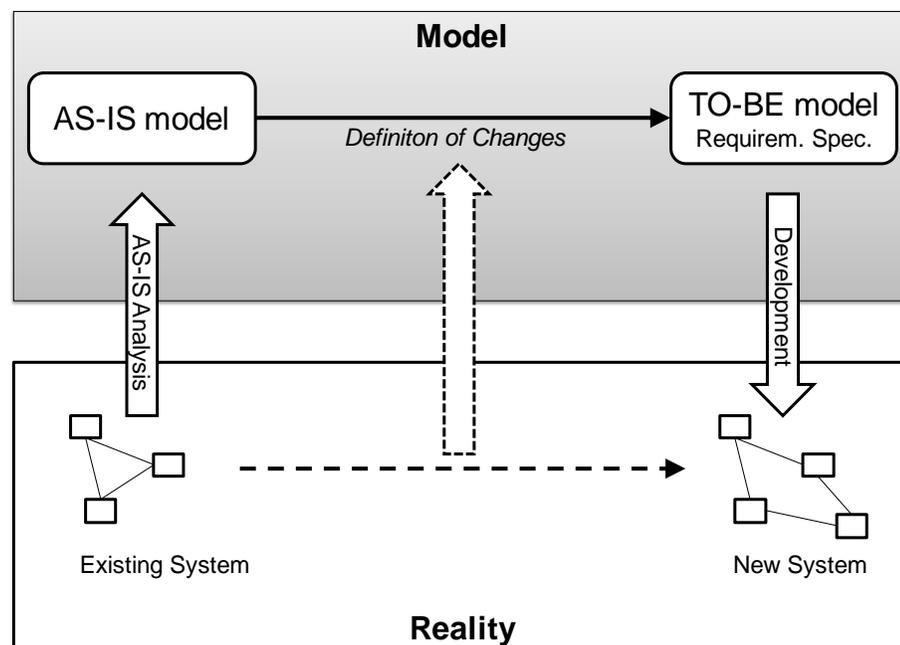


Figure 5: Traditional Systems Analysis [Haumer et al. 1998]

Figure 5 illustrates the connection between the AS-IS and the TO-BE model, which is generated through the AS-IS analysis of the existing system. By defining the required changes on model level, the TO-BE model is created that in principle specifies the requirements for

the new system or solution. Its development (partly) replaces the existing system in reality. To integrate the solution into the environment, the transformation from the old system has to be considered in the definition of changes.

### Essential Systems Analysis

Essential Systems Analysis is a further development of the structured analysis presented in the previous section. Basic idea is the distinction between the essence of a system and its incarnation [McMenamin & Palmer 1988]. The essence of a system is defined as the sum of all true requirements towards the system. A true requirement is a characteristic or functionality that has to be provided by the system independent from its implementation. In contrast to the essence of a system, its incarnation describes the implementation of the system under realistic conditions.

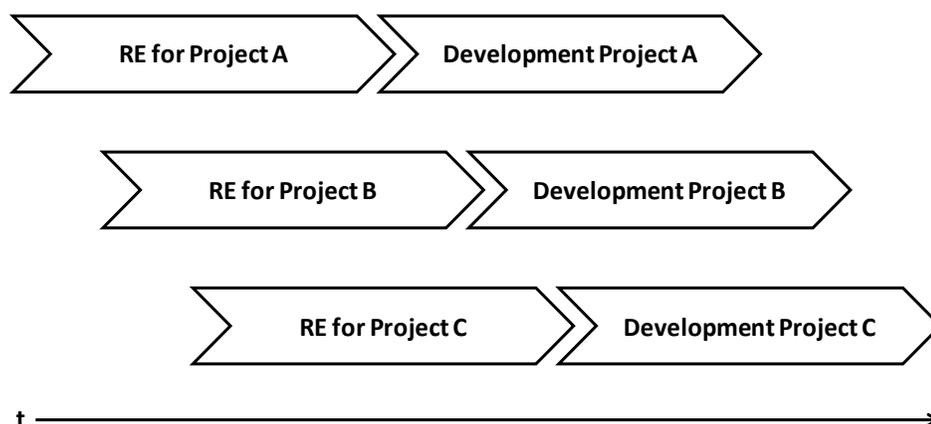
Like the structured analysis, the essential Systems Analysis also uses AS-IS and TO-BE models. However, the AS-IS model is additionally transformed into an essential model, which is used for the definition of changes, leading to an essential TO-BE model. In a further step, the essential TO-BE model is incarnated by choosing the concrete means for implementation, taking into account limiting factors.

The distinction between essence and incarnation allows analyzing the real functionalities of a system, without mixing them with implementation details. Essential models are independent of technological change, which makes them more stable. They are also more compact and easier to understand than incarnation models and do not anticipate decisions about the technology to be used.

#### 2.1.2. Requirements Engineering as a Phase

Nowadays, Requirements Engineering is often seen as a discrete development phase that has the function to create the requirements specification. In this view, a Requirements Engineering process is executed in the beginning of each development project, e.g. as being described in the Waterfall Model [Royce 1987]. The requirements elicited for the project are documented in a requirements specification. This document serves as reference for the subsequent development activities. Requirements are elicited separately for each development project, which is similar to the structured and essential Systems Analysis. The different projects can be conducted sequentially or in parallel [Rausch & Broy 2007].

In a sequential set-up, the requirements for the first system are specified and the system is developed. After finishing the project, the next development project with an independent Requirements Engineering phase can start at any time. In parallel development, the Requirements Engineering activities for different projects are still conducted separately, but can timely overlap with each other or other development activities (see Figure 6).



**Figure 6: Parallel Requirements Engineering as a Phase**

The structured analysis and discrete Requirements Engineering approaches have been developed for automation of established and well understood business processes. Typical examples are accounting or manufacturing processes, which were also incrementally optimized but in principle remained the same.

In contrast, solutions for environments like Manufacturing Service Ecosystems have to offer innovative new functionalities. Future Internet and web-based applications enable completely new collaborative processes. Therefore, tasks for the development of new systems and solutions have changed dramatically. The challenges mentioned at the beginning of this chapter cannot be managed through Systems Analysis and Requirements Engineering as a phase. Furthermore, the traditional approaches incorporate a number of substantial disadvantages, e.g.:

- **Missing continuity:** Requirements Engineering is only conducted for a limited period of time. Changes that occur during development are not reflected in the requirements specification. Because it does not mirror the implemented requirements anymore, it cannot be reused in the future.
- **Necessary AS-IS analysis:** Because requirements are not updated, the specification of the solution is outdated. Often it is not even known, which parts of the requirements specification are really implemented. Any new development project thus needs another time consuming and costly AS-IS analysis. This has among other things an effect on the development time for a solution.
- **No systematic reuse of requirements:** Requirements cannot be reused over development project boundaries. If the same requirements are valid for more than one solution, they have to be engineered separately again.
- **Focus on the current solution:** Focusing only on the current solution to be developed can lead to ignoring information that is not relevant for the development project. However, the information ignored can be important for other development projects.

## 2.2. Implications for Requirements Engineering in Manufacturing Service Ecosystems

Because of the mentioned disadvantages, Requirements Engineering in Manufacturing Service Ecosystems should be executed as a continuous process, which includes all relevant stakeholders and documents all relevant changes on a conceptual level. This enables a faster, cheaper and less error prone development of the solutions in the project [Kruchten 2003].

### 2.2.1. Continuous Requirements Engineering

In contrast to Systems Analysis and discrete Requirements Engineering, which are time limited phases in the development process, continuous Requirements Engineering is a phase and project independent task. It can be executed in different intensities, for which two levels are described below:

- **Phase-independent Requirements Engineering:** On this level, Requirements Engineering is a cross-sectional task that continues along the development process of a solution and secures a consistent and traceable elicitation and management of requirements. There is an ongoing interaction between Requirements Engineering and the development project along the whole life-cycle. Requests for changing

requirements are delivered to Requirements Engineering and changes to the system are documented. Changes can thus be considered in an early stage.

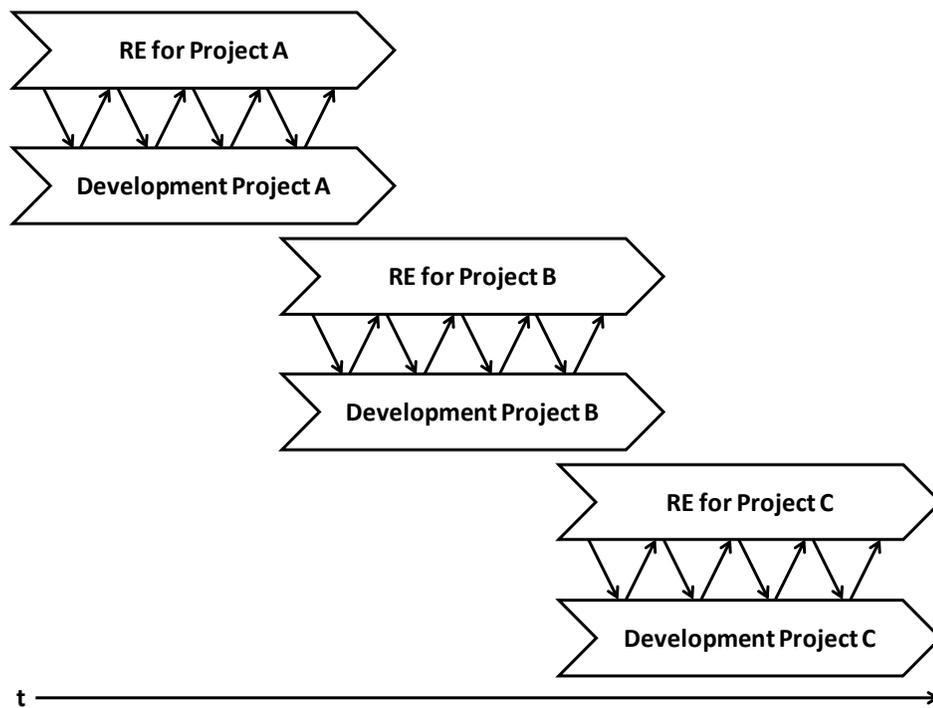


Figure 7: Phase-Independent Requirements Engineering

- Cross-project Requirements Engineering:** This level enhances the phase-independent Requirements Engineering by a continuous requirements elicitation and management, which is not bound to specific development projects. Therefore, the requirements towards a new solution can be compiled from the currently know requirements at any given moment. Subsequently, the solution is implemented on the basis of these requirements. Feedback from the single development projects is constantly integrated into the base of requirements.

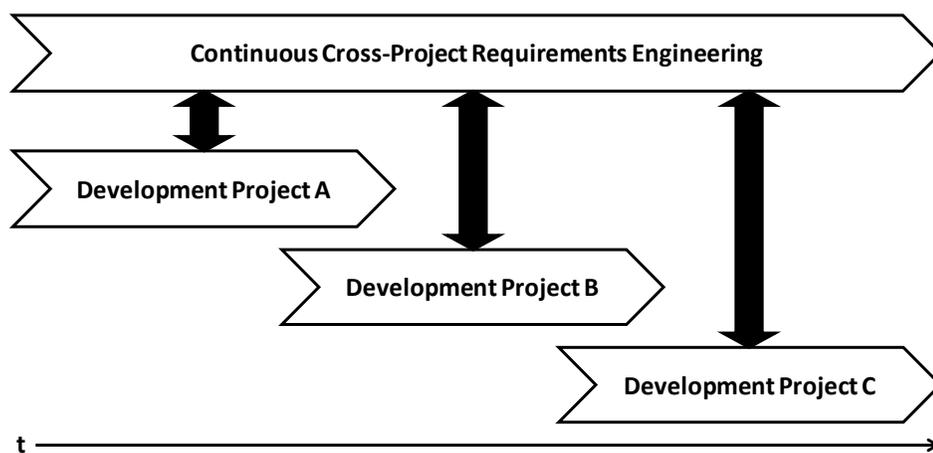
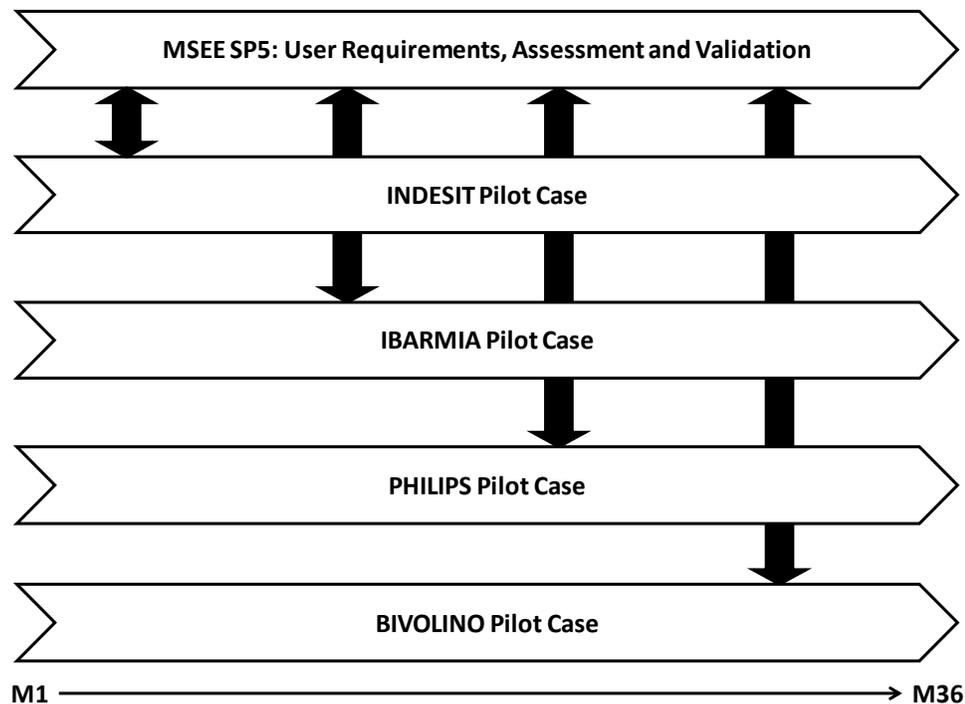


Figure 8: Cross-Project Requirements Engineering

A cross-project Requirements Engineering is advisable if solutions are developed in rapid sequence or if the development projects are concentrated on similar topics, as it will be the case within most Manufacturing Service Ecosystems. In MSEE for example, the implementations for the four end-users are based on the same idea and technological background (see Figure 9).



**Figure 9: Continuous Cross-Pilot Requirements Engineering in MSEE**

If the requirements are collected across the boundaries of a specific business case in a Manufacturing Service Ecosystem, the efficiency is much higher. Drawbacks of a continuous cross-project Requirements Engineering are the increased need for coordination between the development projects and possibly higher costs for Requirements Engineering. However, the coordination between the business cases is a natural component of a Manufacturing Service Ecosystem and the effort for Requirements Engineering has to be planned on this basis from the beginning. The advantages of the approach justify this effort [Pohl 2008]:

- Systematic learning process:**  
 Continuous cross-project Requirements Engineering supports institutionalized learning process for the stakeholders as well as the cross-project exchange of requirements. It enables the continuous development of a knowledge and requirements base, which can be used for the development of future solutions.
- Requirements are up-to-date:**  
 Correctly implemented continuous Requirements Engineering secures that the requirements always reflect the current status of the developments projects and the needs of the end-users.
- Shorter development times:**  
 Continuous Requirements Engineering provides up-to-date requirements. A repeated AS-IS analysis is generally no longer necessary, which decreases the time needed for development of a solution.
- Cross-project reuse of requirements:**  
 Requirements and development artifacts, like components and test cases, can be reused across the boundaries of several development projects.
- Clear responsibilities:**  
 Continuous Requirements Engineering requires the establishment of a Requirements Engineering team, which is responsible for the development, management and update of requirements. The team has a clear responsibility and can concentrate on

Requirements Engineering. Furthermore, all stakeholders have defined contact points for Requirements Engineering and requirements specification.

Therefore, the Methodology for Requirements Engineering in Manufacturing Service Ecosystems will feature a continuous and cross-pilot-case based approach. In MSEE, user requirements (elicitation), assessment and validation is carried out throughout the project (SP5: M1-M36) for all four end-user in parallel (see Figure 9). WP52 “Virtual Factories & Enterprise requirements collection & specification” covers the specification of the MSEE solution from M1-M15, while WP54 “Virtual Factories & Enterprises verification & validation” will accompany the piloting and demonstration of the solution within the four test cases in SP6 from M13-M36.

For administrative reasons, the Requirements Engineering process in MSEE is divided into two subsequent loops, for which the results are presented in deliverables D52.1 “First end-user requirements for Virtual Factories & Enterprises in Manufacturing Service Ecosystems” (M4) and D52.2 “Second iteration end-user requirements for Virtual Factories & Enterprises in Manufacturing Service Ecosystems” (M15). However, the experiences in the pilot cases are continuously fed back into requirements specification during the project.

### **2.2.2. Serious Games for Requirements Engineering**

The use of Serious Games for Requirements Engineering is based on the experiences gained in the COIN IP<sup>2</sup>. The distinctive characteristic of a Serious Game is that it is not used for entertainment purposes. In fact, it is rather used for simulation/testing or professional training, like in flight simulators. But also in business education Serious Games are used to teach students complex interrelations and strategies in value chains. The following advantages can be identified in using Serious Games [Thoben & Schwesig 2007], [Jarke 2007]:

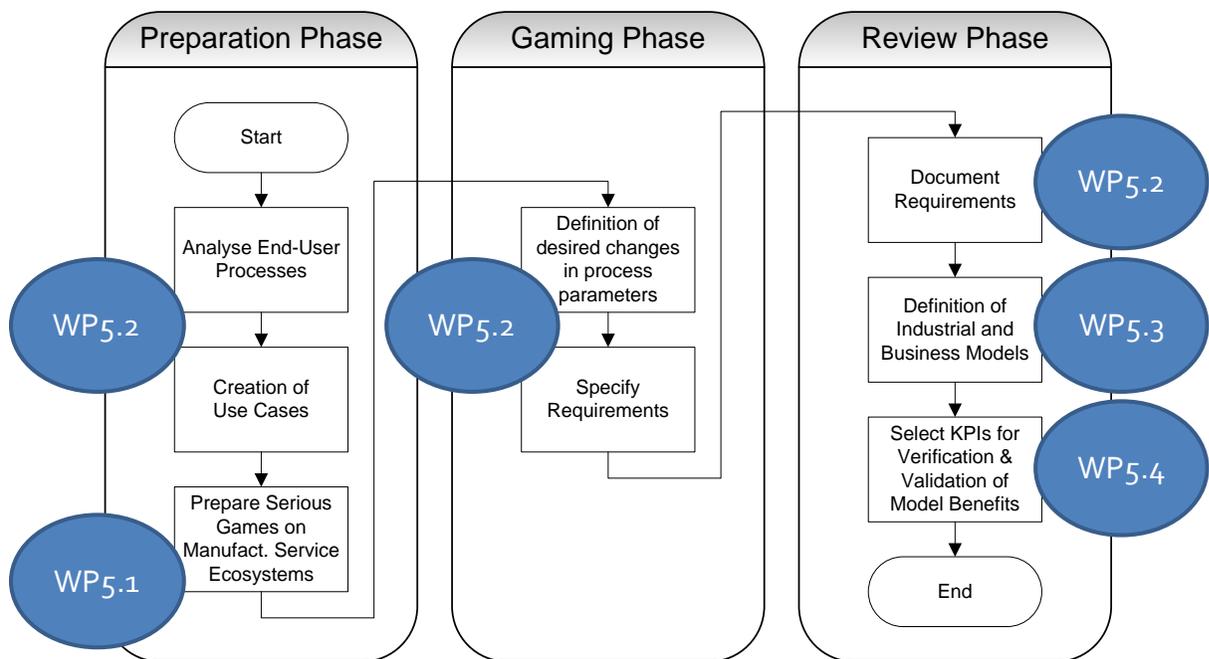
- The basic principles are known from entertainment games
- The participants have to actively develop own strategies
- Mistakes will not have negative consequences in reality and can be used to learn
- Knowledge can be practically applied in a realistic setting

The mentioned advantages have led to the decision to apply Serious Games for Requirements Engineering in Manufacturing Service Ecosystems. Other advantages of using a game based approach lie in the nature of the collected information. While the approaches analyzed in D51.1 mostly require the end-user to know exactly what he needs, this is not possible in complex environments. The innovative nature of the project demands for radical innovation. This is supported by Serious Games in helping the end-users to identify problems in their business routines, which can be translated to meaningful requirements when they emerge.

Taking into account the results of D51.1 and the experiences from the COIN IP, a Serious Gaming approach is chosen to support Requirements Engineering in Manufacturing Service Ecosystems, guiding the end-user through the iterative elicitation and validation of requirements. However, the COIN Serious Game did not include the use of indicators to measure the validity of the requirements. Thus, the technique will be refined and extended to involve KPI's. The approach has already been proposed in D51.1, the process is shown again in Figure 10. The three phases will now be described in detail below.

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<sup>2</sup> <http://www.coin-ip.eu>



**Figure 10: Approach for Serious Games in Requirements Engineering and the associated MSEE Work Packages.**

The process of Requirements Engineering with Serious Games can be divided into three phases (see Figure 10):

- Preparation phase
- Gaming phase
- Review phase

In MSEE, the preparation phase has already started with the analysis of the end-user processes to create the specific Use Cases for each TO-BE scenario. In a next step, the Serious Games will be prepared on this basis in a Manufacturing Service Ecosystem context. By playing the Serious Game in the gaming phase, the end-users requirements toward changes in process parameters are captured and suitable indicators for impact evaluation can be selected. The review phase combines aspects of requirements analysis, specification and validation. The new Serious Gaming approach is described in detail in the following section.

### 2.2.2.1 Preparation Phase

The preparation phase deals with the preliminary identification of needs during early meetings with the end users and the creation of current business use cases and the accompanied scenario descriptions. Also, the Serious Games are adapted during the preparation phase and the scenarios are implemented. The preparation phase provides the foundation for the later elicitation of requirements through Serious Gaming.

In MSEE, the preparation phase has already started with WP52 analyzing the end-user's business processes from M1. Guided Questionnaires for validation of the AS-IS scenario have been circulated to set up the first requirements workshop in MSEE end of M2. The first rough set of innovative requirements that has been elicited is documented in D52.1.

After the first requirements workshop, the AS-IS scenarios of the MSEE end-users have been validated and detailed by the analysis of industrial end user's processes. The end-users have defined first ideas of a TO-BE scenario (Product+Service or Product2Service) for the specification of innovative user requirements. The specific use cases have been discussed in a second requirements workshop in M6 and will be described finally until the end of M7.

In the further steps, business scenarios will be created from the use cases and implemented in the Serious Games until M10. M10 and M11 will be used to prepare and run a gaming workshop, which is described in the gaming phase below.

### 2.2.2.2 Gaming Phase

The gaming phase is based on the results from the preparation phase. It can be divided into the gaming workshop and online-playing sessions that will take place after the workshop. In this phase, the desired changes in process parameters are defined by the end-users and the requirements are derived. The main objective during the gaming phase is the collection of detailed requirements and KPIs for validation by the end users using two different games.

For MSEE, the Serious Games, namely **Seconds** and **refQuest**, are further developed from software that has already been applied in the COIN IP to support the development of needs on future services. However, they have been modified to also include the selection of KPI's for validation of the elicited requirements. The conceptual model of the gaming approach used for the collection of user requirements in MSEE is shown in the following Figure 11:

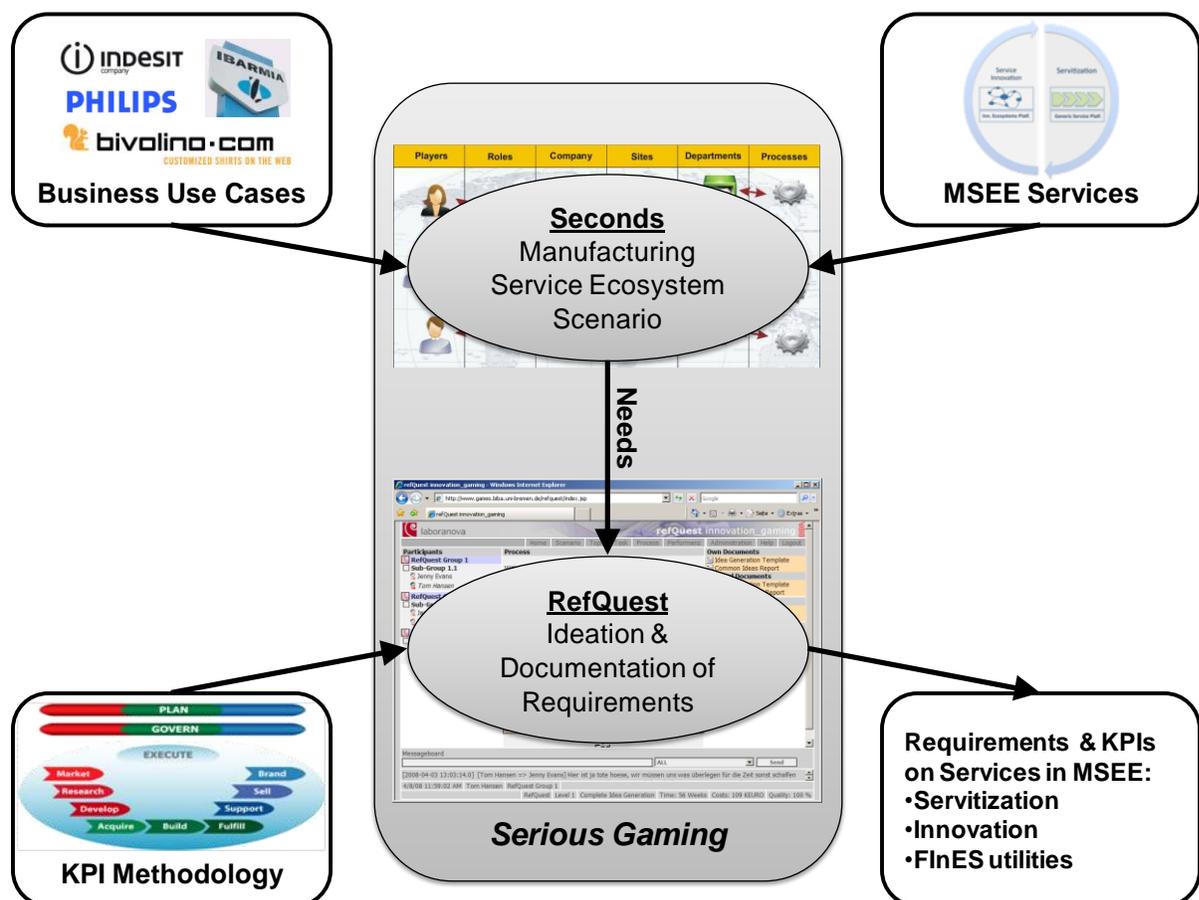


Figure 11: Serious Gaming approach in MSEE

The approach can be described by the following steps:

1. Integration of the end-user business use cases and the MSEE services into a Manufacturing Service Ecosystem Scenario in **Seconds**
2. Identification of needs using **Seconds**
3. Integration of the KPI methodology into **refQuest**
4. Refinement of needs into requirements and selection of KPIs using **refQuest**
5. Specification of KPIs and requirements.

In the first step, the multiplayer game Seconds, which simulates the business scenarios defined in the preparation phase in Manufacturing Service Ecosystem is used. This game will verify the services proposed by the MSEE development SP's as well as support the identification of additional requirements the end users have on the services. Seconds is a game which simulates a complex business scenario that consists of several systems, and allows the end users to reflect upon their own use case, even though playing in a common generic scenario.

In the second step, a game for supporting the first phase in an innovation process, the idea generation or often also called the ideation phase developed within the LABORANOVA<sup>3</sup> project, will be used. This refQuest game allows the end users with the possibility to play different scenarios. They will be used to elicit specific requirements in more detail on servitization, for the innovation ecosystem and for elaboration of requirements on utility and FInES services. Each scenario needs to be played three times, in order to develop requirements taking three different perspectives into consideration.

### 2.2.2.3 Review Phase

The review phase starts after the gaming workshop has been conducted and is used to analyze and document the data generated during gaming. It consists of the analysis and documentation of the requirements from Serious Gaming. On this basis, a specification is developed and KPI's are selected for the validation of the impact.

In MSEE, the outcome of the Serious Games sessions will be checked for gaps and limitations in the services provided by the project, which will be documented as additional requirements for the developers. Furthermore, the specific requirements of the players that have been elicited for servitization, the innovation ecosystem and the utility and FInES services in the second step, will be analyzed and used for the further enhancement of the requirements specification.

### 2.2.2.4 Schedule for Serious Gaming in MSEE

M4	M5	M6	M7	M8	M9	M10	M11	M12	M13	M14	M15
<b>D52.1: Preliminary User Requirements Analysis</b>	Concept for Serious Games in MSEE (D51.2)		Prepare Serious Games		Implement Business Scenarios in Games		<b>Prepare and run Gaming Workshop</b>		<b>D52.2: Final User Requirements Analysis</b>		
	Fix Use Cases for each End-User		Create Business Scenarios		Analyse and document Data from Workshop						

**Figure 12: Schedule for Requirements Elicitation through Serious Games in MSEE**

WP52 has the aim to collect the end-user requirements for the MSEE services. Figure 12 shows the schedule for the application of Serious Games for this task. Preliminary user requirements have already been collected and documented in D52.1. This deliverable, D51.2,

<sup>3</sup> See <http://www.laboranova.com/>

presents the concept for the application of Serious Games in MSEE. Currently, the use cases for each MSEE end-user are re-analysed and fixed. On this basis, business scenarios will be created for the games. At the same time, the Serious Games are prepared and the business scenarios are implemented into the game play.

In M11-M12, the gaming workshop will be prepared and run with all involved stakeholders. A description of the two games used in this process, namely Seconds and refQuest, is given in a later section. The end users will have some time to continue playing after the workshop. Finally, the results gathered at the workshop will be analysed and documented in the deliverable D52.2.

The following sections present the implications of the methodology for Requirements Engineering in MSEE on the four steps of requirements elicitation, requirements analysis, requirements specification and requirements validation (see Figure 1).

### **2.3. Requirements Elicitation**

Requirements Elicitation is used to determine the relevant requirements for the development of a solution. The solution should bring the greatest possible benefit for the goals, objectives and motives of the involved stakeholders, assuming they are correctly understood. In D51.1 “Applicability of existing user requirements approaches in MSEE” various state-of-the-art approaches for requirements elicitation have been analyzed for their applicability in the MSEE context.

The analysis has revealed the unequal suitability of creativity, observation and interview techniques in Manufacturing Service Ecosystems. Creativity techniques can be used to generate a first rough set of requirements that does not depend on an existing solution for innovative ideas. Observation techniques are independent from human influences, but their application takes time and can be used for detailing requirements. Interview techniques are suitable for the elicitation of conscious requirements at any stage of the project.

#### **2.3.1. Approach for Generation of Ideas for the TO-BE Scenarios**

On the basis of the analysis in D51.1, the following elicitation approaches have been selected for eliciting a first rough set of requirements in Manufacturing Service Ecosystems:

1. Guided Questionnaires
2. Requirements Workshop
3. Focus Groups
4. Brainstorming

In accordance with the proposed approach, requirements elicitation in MSEE has started with the early provision of a guided questionnaire and a use case template to the four end-users already at the beginning of M2. The main reason for this approach has been to validate their AS-IS scenarios described in the DoW in a structured way. If necessary, the end-users received help for filling the questionnaire by the WP52 leader and their scientific and technological partner in the project.

Based on the results of the questionnaires that mainly model the AS-IS situation for the end-users, a requirements workshop has been organized end of M2 to generate first ideas for TO-BE scenarios. To guarantee a representation of all relevant stakeholders in MSEE, the following partners participated in the meeting:

- Representatives for all four pilot cases to represent the customer/end-user viewpoint

- SP1, SP2 and SP3 leaders to represent the development perspective
- One scientific or technological partner per end-user for the implementation viewpoint
- The MSEE coordination team for the project objectives and goals perspective

In a three day schedule, first focus groups have been formed for each end-user to derive basic requirements from the AS-IS situation. In a second step, brainstorming was introduced to develop first ideas for TO-BE scenarios, which were consolidated on the last day of the workshop. The results of the elicitation of a first set of rough requirements are documented in deliverable D52.1 “First end-user requirements for Virtual Factories & Enterprises in Manufacturing Service Ecosystems”, which has been published in M4.

In order to detail their scenarios on a solid basis, the end-users needed more information about the concepts and possible services provided by MSEE. Therefore, a second requirements workshop has been organized in M6 for all industrial pilot cases. The goal of this meeting has been to discuss the requirements of each end-user against the planned or possible developments in the project. As a result, a framework for the TO-BE scenario has been defined for each case, which will subsequently be detailed to concrete requirements.

### 2.3.2. Elicitation of Requirements using Serious Gaming

In the further course of requirements elicitation, end-user individual interviews can be used to concretize the requirements for the specific case. In MSEE, this has already started in M6 with the BIVOLINO case and will subsequently be conducted for the other end-users. However, interviewing is only partly suitable to identify requirements for *complex solutions*. The end-user might not really be aware of his needs and the implications of a radical redesign for servitization. Furthermore, *information exchange* between the end-users is not really supported. Therefore, Serious Games may help to support user requirements collection in Manufacturing Service Ecosystems. For MSEE, the games **Seconds** and **refQuest** have been selected for this task.

### 2.3.3. Seconds

#### General description

The Serious Game **Seconds** is being developed in BIBA for training on strategic decision making. It has already been used in laboratory classes at the University on Bremen and for requirements elicitation in the COIN IP. Seconds has a manufacturing scope and lets the user make strategic decisions within game play. The general scenario simulates a complex business environment with capital markets, government, labor market etc. In the game, the user plays a role in a company and is able to establish new sites, new departments and processes. In order to succeed, he has to collaborate with business partners and to take risky decisions (see Figure 13).



**Figure 13: Overview of a generic Collaboration Scenario**

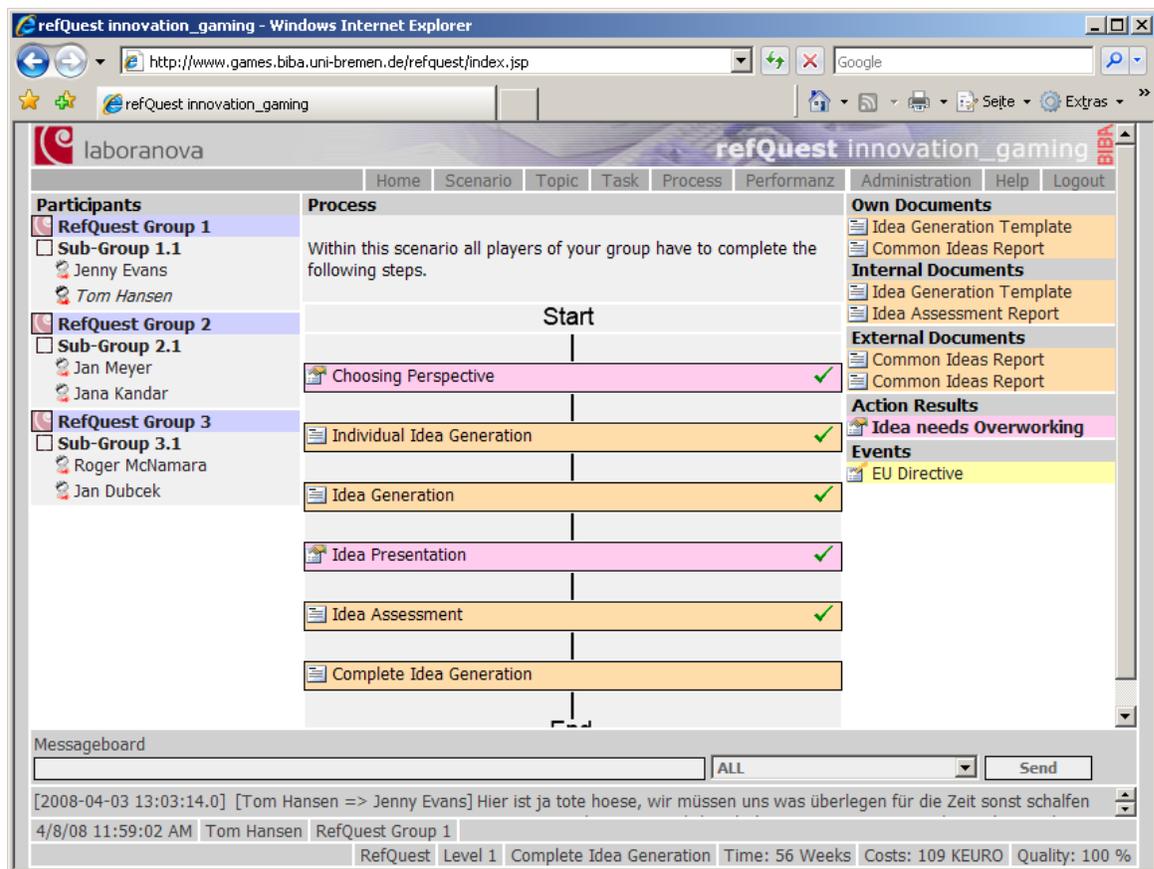
### The use of Seconds in MSEE

In MSEE, Seconds will be used to verify if the MSEE services defined by the developing subprojects SP1, SP2 and SP3 do offer the functionalities the end users need. These services are based on a preliminary requirements specification and might need extensions and modifications. The services are shortly described in the gaming scenario, and users have the possibility to define new services which they need or add comments to the existing ones.

#### 2.3.4. refQuest

##### General description

RefQuest allows the user to look at a given problem from different perspectives. In subsequent rounds of idea generation, the perspective on the problem will change. The game is played in so-called ideation groups with different innovation perspectives, which also can change during the game. As outcome, the central problem – the challenge or opportunity for the organisation – is developed into a product idea, value proposition, user need, central question or area of strategic interest.



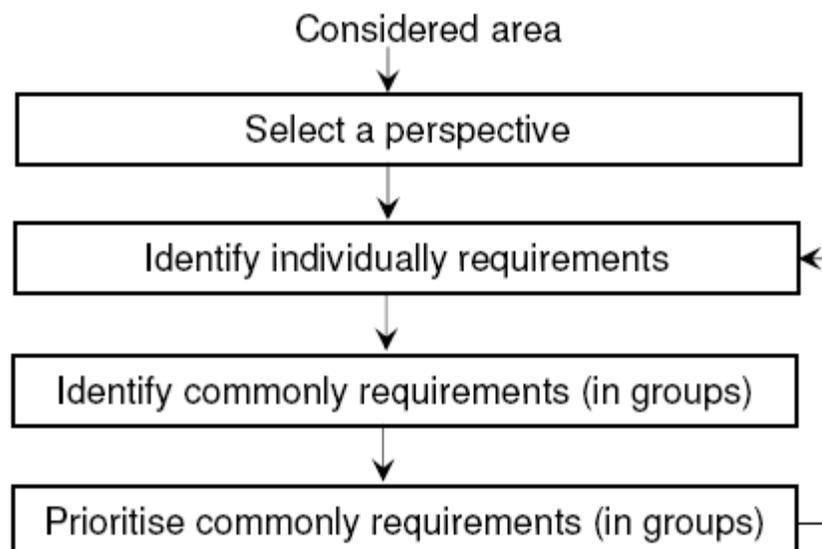
**Figure 14: The refQuest Gaming User Interface in a Web Browser**

refQuest is played sequentially along a game scenario describing the environment, the situation, the topic as well as the role description. The users get a common understanding of the game process from the beginning. Inside the game, several processes are adaptable and require the player to act, e.g. choose a perspective for idea generation or to complete a document with ideas in a structured way. Events can be set additionally by the game facilitator and motivate the user to think in new ways. KPI's can be integrated into idea generation to measure time, cost and quality during the game as a competing effect.

### **The use of refQuest in MSEE**

In MSEE, refQuest will be used to elicit end users' requirements on the MSEE services, which are being developed within the project. There are three refQuest scenarios that the end users are supposed to play. They will be based on the MSEE innovation cycle, featuring servitization, innovation ecosystem and service innovation. The end users have to choose those most important for their own company. Additionally, in each scenario the player will choose between the following three perspectives:

1. Manufacturing
2. Ecosystem
3. IT



**Figure 15: The refQuest Process for Requirements Specification**

Figure 15 shows the process for requirements specification in refQuest. For requirements elicitation, the end user needs to play each of the three perspectives, i.e. to play each scenario three times. Following this step, the five most important requirements are to be chosen and described more detailed. Then, the end users have to collaborate and choose again the five most important requirements for further elaboration. Finally, a collaborative ranking of relevance and priority of the requirements takes place and KPI's to evaluate the fulfilment of the requirements are determined.

## 2.4. Requirements Analysis

Requirements analysis is used to ensure the quality of the elicited requirements. The quality of requirements is determined through certain quality criteria. Thus, the quality of the set of collected requirements depends on the quality of the single requirements and on specific criteria relevant for a set of requirements [IEEE 1998], [Robertson 2006]. Some quality criteria for requirements have already been given in D51.1, please see that deliverable for further details. In this section, the quality criteria used for requirements analysis in MSEE are presented and it is shown how the methodology for Requirements Engineering will help to ensure their observation.

- **Completeness**  
The requirement is complete, if there is no tolerance for amendments by any of the stakeholders, i.e. there are no gaps in regards to the content of the requirement. A set of requirements is complete, if all requirements towards the functionality, performance, constraints and external interfaces are included. In MSEE, completeness of requirements is ensured by the simultaneous participation of all stakeholders in the Serious Gaming sessions.
- **Consistency**  
The requirement is consistent, if its contents do not contradict each other. A set of requirements is consistent, if there are no conflicts between the single requirements in the set. In MSEE, consistency of requirements is ensured by the refQuest process for requirements specification, which combines the individual requirements of the stakeholders to a common consistent set.
- **Traceability**  
The requirement is traceable, if its source, its evolution as well as its influence on the

solution to be developed can be tracked. A set of requirements is traceable, if its structure allows for easy, complete and consistent modification of requirements. In MSEE, traceability of requirements is ensured by using standardized templates and rules for the documentation of requirements (see section 2.5)

- **Relevancy**  
 The requirement is relevant, if the stakeholders acknowledge its necessity to implement the properties with a concrete benefit for one of them. In MSEE, relevancy of requirements is ensured by the refQuest process for requirements specification, which contains a collaborative decision on the relevance of the conceived requirements.
- **Unambiguity**  
 The requirement is unambiguous, if it cannot be interpreted in a different way. In MSEE, unambiguity of requirements is ensured by the collaborative nature of Requirements Engineering. The interpretation of each requirement is discussed among the stakeholders and the verbalization is optimized accordingly.
- **Understandability**  
 The requirement is understandable, if its content can be easily comprehended by all involved stakeholders. In MSEE, understandability of requirements is ensured in the same way as unambiguity. The discussion among the stakeholders leads to a common understanding of requirements.
- **Verifiability**  
 The requirement is verifiable, if the to be solution can be tested for the fulfillment of the requirement. Typically, this includes the definition of testing criteria. In MSEE, verifiability of requirements is ensured by the definition of KPI's or success criteria for each requirement, which is included in the Serious Gaming approach.
- **Priorization**  
 The requirement is prioritized, if it is weighted by its importance and/or stability. In MSEE, prioritization of requirements is ensured by the refQuest process for requirements specification, which contains a collaborative ranking of relevance and priority of the requirements.
- **Currentness**  
 The requirement is up-to-date, if it represents the current needs towards the solution to be developed and its context. In MSEE, currentness of requirements is ensured by the continuous Requirements Engineering approach, where requirements elicitation, analysis and validation is carried out throughout the project.

## 2.5. Requirements Documentation and Specification

There is a slight difference between documentation and specification of requirements. After elicitation, the requirements are in most cases only implicitly available in the form of protocols or drafts. The Requirements Engineering team from WP52 analyzes this material, to document the requirements according to the pre-defined templates and rules. Specification of requirements goes beyond the pure documentation and connects the requirements with the solution to be developed. Therefore, requirements specification will be conducted together with the development partners in MSEE.

### 2.5.1. Documentation of Requirements

Goal of requirements documentation is to record important information from all activities of Requirements Engineering. The main advantages of a professional documentation are [Kovitz 1998], [Sommerville & Sawyer 1997]:

- **Persistence**  
The huge amount of information generated during the project could not be memorized without documentation.
- **Common information basis**  
All project members have access to the same information.
- **Supports communication**  
The documentation process enables discussions on the contents and thus communication between the stakeholders.
- **Advocates objectivity**  
In contrast to the verbal exchange of information, documented information is more stable and less subjective.
- **Lower dependency on knowledge carriers**  
In most cases, not all information in a project is known to all project partners. Documentation enables the provision of relevant information to all project partners and reduces the dependency on single knowledge carriers.
- **Reflection**  
The documentation process leads to a deeper thinking about the documented information. In this way, errors or missing information can be uncovered more easily.

Different notations can be used to document requirements. The most common form is using natural language (in contrast to artificial or modeling languages). Natural language makes it possible to communicate nearly any information about requirements between stakeholders. Nevertheless, using natural language underlies some restrictions as well [Kamsties 2001], [Berry et al. 2003]:

- **Advantages of using natural language for documentation:**
  - *Universal:* Documentation in natural language is universal, because it is not restricted to a certain problem domain.
  - *Flexible:* Natural language is flexible, because it enables variable abstractions and detailing.
  - *Easy to use:* Natural language documentation is easy to use, because no training or special tools are needed in the process.
- **Disadvantages of using natural language for documentation:**
  - *Underspecification:* Documented requirements can be interpreted in different ways, if underspecified. This means, that missing details allow for more than one interpretation of the requirement.
  - *Ambiguity of the natural language:* In this case, ambiguity of a requirement is caused by the fuzziness of the natural language itself. This can be a significant problem.

The advantages of documenting requirement in natural language make it the primary choice for Requirements Engineering in MSEE. It is usable and understandable by all stakeholders in the project and thus creates the connection between the end-users and development partners.

The manufacturing, organizational and IT domain can be equally described in natural language. Furthermore, requirements documented early in the project can easily be detailed in a later phase.

However, the identified disadvantages have to be addressed to make natural language documentation an effective tool for Requirements Engineering. The provision of a reference structure can help to avoid underspecification and ambiguity of requirements. A widely used structure for documenting requirements in natural language is requirements lists [Kulak & Guiney 2000]. The lists structure requirements in tabularic form, for which different guidelines exist [Young, 2004]. An example is given in Table 1 below:

**Table 1: Requirements List Example**

<b>Subproject</b>	<b>SP2</b>	
<i>Transition Domain</i>	<i>Service</i>	
<b>No.</b>	<b>Requirement</b>	<b>Requested by End-User</b>
<b>SP2.s.3</b>	Simulation of business model (WP2.4)	Philips, Indesit, Bivolino
<b>SP2.s.4</b>	Monitoring the transition (KPI), both operational and business aspects (WP2.4, WP1.3)	Philips, Indesit, Bivolino
<b>SP2.s.5</b>	Legal/ contractual issues management (WP2.5), Security&Privacy (SP3)	Ibarmia

For the documentation of previously collected user requirements, the requirements lists will be used as an appropriate documentation style. The end user requirements will be provided by means of requirements lists for further specification.

### **2.5.2. Specification of Requirements**

While the requirements lists specify “what the system should do, without specifying how” [Lauesen 2003], system requirements include by definition, the “how” as far as they represent implementable system specifications. Therefore, specification of requirements in MSEE will use service system modeling provided by SP1, which is based on enterprise modeling from the system theory approach.

Enterprise modelling aims at representing an enterprise in terms of its structures, organisation and operations from various points of view [Doumeingts 2000]. It is used to externalise enterprise knowledge in a semantic unification space where shared concepts can be defined, mapped to one another and communicated in the form of enterprise models [Vernadat 2003], [Goranson, 1997]. The following aspects make enterprise modeling useful for the specification of requirements:

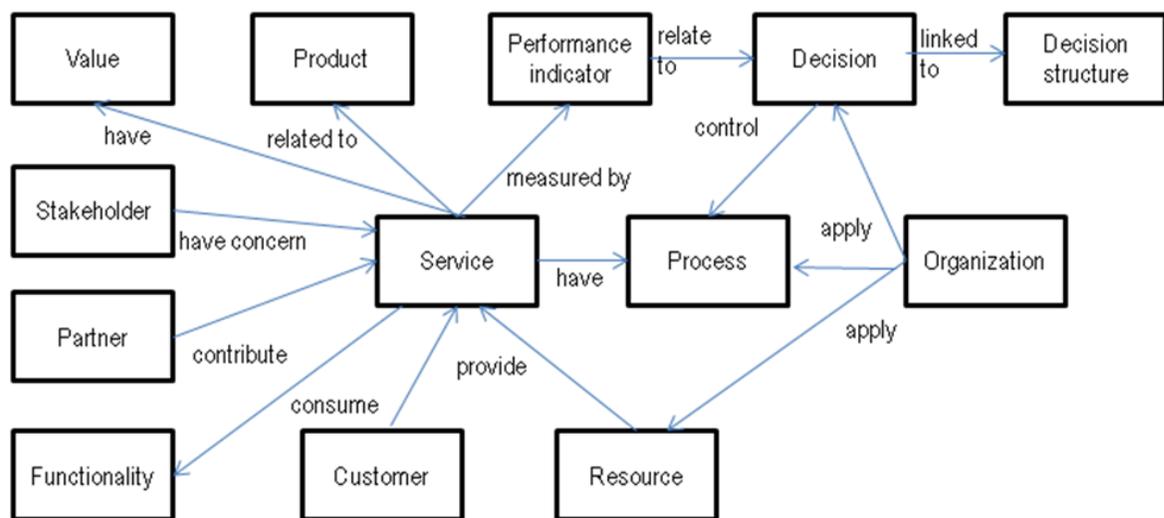
- Representation of the AS-IS and TO-BE systems in terms of functions, business processes, physical system, decision system and IT system. The comparison between the AS-IS and TO-BE system allows to identify the required changes to the system design.
- Specification of the future system design at various levels of abstraction through a model driven approach and thus specification of system requirements.

In MSEE WP11, service modeling language concepts and constructs are defined under the frame of MDSEA at BOM, TIM and TSM levels (see D11.1). The modeling of requirements is located on the BOM level of the MDSEA (see Figure 16):

Modelling level \ Lifecycle phase	BOM	TIM	TSM
Identification			
Concept			
Requirement	X		
Design	X	X	X
Implementation			X
Operation			
Decommission			

**Figure 16. System Lifecycle and Modelling Levels**

At BOM level, the concepts in Figure 17 are adopted as modeling constructs<sup>4</sup> to represent the service system. Each construct is further described by a template, a graphical representation and a text to explain some specific concerns and detail.



**Figure 17. Modeling constructs and relationships at BOM level**

*“In MSEE, considered service is related to a product. To develop such a service, various stakeholders (providers, intermediary, engineers, etc.) may express their specific concerns. Partners are integrated stakeholder of the virtual enterprise providing services. Service is used / consumed by customers. Service System provides functions which are utilities to fulfill customer’s needs. Service has therefore value(s). Service provided can be evaluated by a set of performance indicators which are related to a set of decisions which control the service system, i.e. to a set of objectives, and decision variables. Decisions are related in a decision structure where consistence / coherence must be analyzed. To provide service to customer, process(es) is/are in general needed to be defined and followed at run time.”<sup>5</sup>*

In MSEE Requirements Engineering, the above constructs can be used to specify concrete system requirements (“how”) for service system engineering from the user requirements

<sup>4</sup> Construct = Concept + its representation (template, graphics, text)

<sup>5</sup> MSEE deliverable D11.1

documented in the requirements lists. The following existing modeling techniques for the modeling of the service systems at BOM level are proposed:

- IDEF3 process diagram to describe the process
- IDEF0 actigram to model functionality
- GRAI grid and nets to model decisions, decision activities and decision system structure
- Organization chart to represent Organization structure
- ECOGRAI to define Performance Indicator Systems

Where there are no existing graphical modeling languages for a construct (Service, Resource, Product, Value, Stakeholder, Partner and Customer), templates are used to capture BOM model information (see Table 2 as an example, the other templates can be found in MSEE D11.1):

**Table 2: Template for Service Description**

Header	
Construct label	[“Service”]
Identifier	[Identifier of the service instance]
Name	[name of the service instance]
Body	
Domain	[Domain of the service]
Description	[Short textual description of this service instance]
Objective	[Short textual description]
Constraint	[Short textual description]
Nature	[“Physical” or “Information” or “human”]
Relationships to other model elements	
PRODUCT	[Identifier/name of Product concerned by the service: described by Product template]
FUNCTIONALITY	[Identifier/name of functionality of the service: described by Functionality template]
RESOURCE	[Identifier/name of Resource providing the service: described by Resource template]
PROCESS	[Identifier/name of Process providing the service: described by Process template]
CUSTOMER	[Identifier/name of Customer consuming the service: described by Customer template]
DECISION	[Identifier/name of the decision controlling the service: described by decision template]
PERFORMANCE	[Identifier/name of the performance of the service: described by Performance template]
VALUE	[Identifier/name of the Value of the service: detail will be described by Value template]
STAKEHOLDER	[Identifier/name of the Stakeholder: detail will be described by Stakeholder template]
Other Relationships	
RELATED TO MODEL LEVEL	[Refer to BOM, TIM, TSM modelling level] : BOM
REALTED TO SLM PHASE	[Refer to service lifecycle phases] : Requirement

Requirements specification in MSEE will be conducted according to the iterative approach used for Requirements Engineering. The templates will be used to capture the related information from the end-users and then elaborate graphical representations. The graphical representation provides a good basis for further discussions and detailing of requirements and the update of the templates.

## 2.6. Requirements Validation

Requirements are the basis for all subsequent design, implementation and testing activities in the development process of a solution. Errors in requirements are therefore affecting all of those activities in a negative way. An error that is only discovered when the system is already in use demands for the revision of all previous development activities. Serious errors in requirements therefore create the risk of not fulfilling time, cost and quality goals for the solution. Requirements validation generates some additional effort during Requirements Engineering, but reduces risks and cost of errors for later development phases [Baziuk 1995].

Requirements are the product of a complex course of activities. This process can lead to inaccuracies, which makes it necessary to validate the documented requirements with the real needs of the stakeholders in defined intervals. Result of this requirements validation is the decision to use the collected requirements for the development of the solution.

An effective requirements validation does not only review the requirements themselves, but equally the activities that have created those requirements and the inputs used in that process [Pohl 2008]:

**1. Find errors in the documented requirements:**

- Has the template for requirements documentation been used?
- Have the rules defined for documentation been observed?
- Have all (changed) requirements been agreed with the involved stakeholders?
- Have all known conflicts over a certain requirement been solved?

**2. Find errors in the inputs used for Requirements Engineering:**

- Have all relevant objects for the solution been identified correctly?
- Have all relevant sources of requirements been considered?
- Has the usage of the solution by all relevant stakeholders and systems been considered?
- Have all required interfaces and technologies been considered?

**3. Find errors in the conducted Requirements Engineering activities:**

- Has the execution of the activities been documented in the defined way?
- Have all activities required according to the methodology been executed?
- Have all required inputs been used for the execution of each activity?
- Have the defined outputs been created by each activity?
- Have all relevant stakeholders been involved in each activity?

The continuous approach used in MSEE involves all stakeholders in any Requirements Engineering activity and thus makes requirements validation a task which is automatically and instantly performed on all collected requirements. Therefore errors should be identified and corrected even before documentation of the requirements. However, backup procedures have been defined, if this should not be the case.

**2.6.1. Validation of the Documented Requirements**

The rules and template for documentation of requirements are provided by WP52 “Virtual Factories & Enterprise requirements collection & specification” (see section 2.5) and its use by the stakeholders will be observed and guided by the Requirements Engineering team and the refQuest software. Furthermore, all created documents are cross-checked in WP52 for their compliance with the standards agreed.

By using the Serious Gaming approach for Requirements Engineering, the stakeholders will collaboratively not only review their own needs, but also the needs of the other stakeholders. Therefore, all requirements and changes to the requirements are constantly available to all stakeholders and an agreement on them can be reached during game play. Should conflicts arise over a certain requirement, several levels of escalation are available for resolution. First, the conflict may be solved during the collaborative gaming sessions themselves. If this is not possible, the Requirements Engineering team will set up a special workshop session in which the conflicting stakeholders can creatively work on a resolution. Finally, a persisting conflict will be submitted to the project management board for decision.

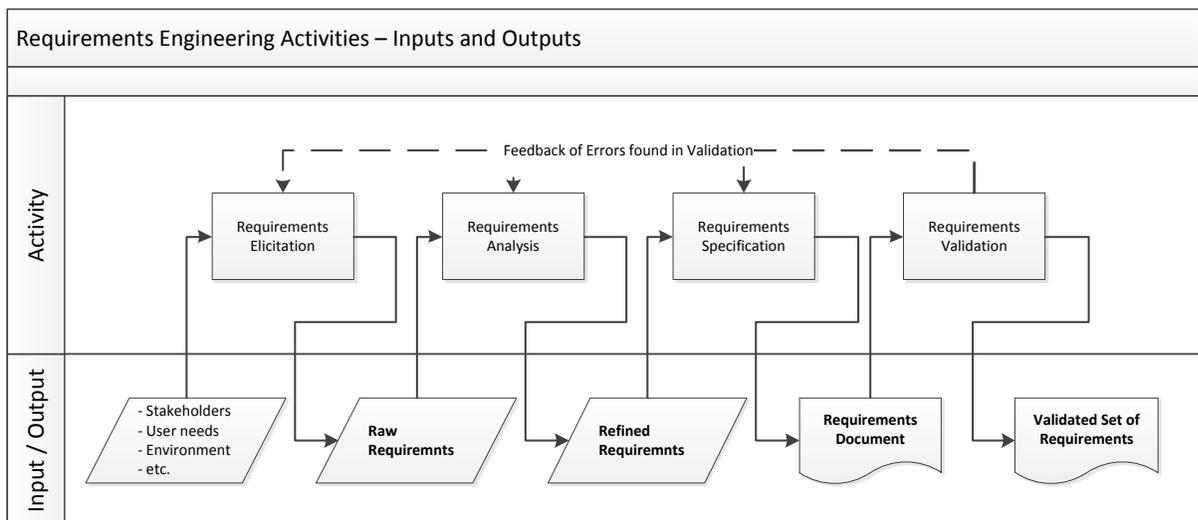
### 2.6.2. Validation of the Inputs for Requirements Engineering

The integrity of the inputs used for the Requirements Engineering process in MSEE is also supported by the collaborative and continuous approach used. By working closely together with the end-users and fostering collaboration among them, the Requirements Engineering team is able to get a deep insight into the relevant objects for a solution and the relevant sources of requirements for each stakeholder. Through comparison between the known inputs from each stakeholder, it is also possible to identify missing content for each case.

Requirements workshops, which are organized individually with the individual end-user and their scientific and technological partner, enable the participation of the intra-company stakeholders of the solution as well. This includes the later users and also the system administrators, which give input about the existing system architecture, the required interfaces and the technologies used.

### 2.6.3. Validation of the Requirements Engineering Activities

The execution of all Requirements Engineering activities, as being described in this methodology, will be documented in the appropriate format (minutes, questionnaires, photos etc.). The aggregated information is collected in the “User Requirements Analysis for Virtual Factories & Enterprises in MSEE” deliverables defined in the DoW. Namely, these are D52.1, which has already been submitted M4 and D52.2, which will be submitted M15. These deliverables make it possible to follow up on all executed activities and validate them with the methodology describe in this document.



**Figure 18: Inputs and Outputs of the RE Activities**

Figure 18 lists the inputs and outputs of the activities used for Requirements Engineering to enable a cross-check with the involved stakeholders. In that way, it can be validated if a stakeholder or an important input or output has been missed. Furthermore, collaboration with the development partners constantly feeds back specific requests for information to the Requirements Engineering process.

### 3. Performance Indicators for Manufacturing Service Ecosystems

Performance Indicators (PI) are indicators for the quantitative, reproducible measurement of a factor, a condition or a process in a system. In economics, PI's are used to make business processes measurable and thus capable of improvement. They are basis for decision making (identify problems, strength and weaknesses) controlling (planned vs. actual value), documentation and/or coordination of interdependencies in a company. A PI is chosen from the existing information inside the company as a particular significant indicator.

PI's can be selected and measured on different decision levels. On the one hand, strategic indicators can be used to globally measure the performance of the system as a whole, while on the other hand tactical and operational PI's measure parts of the system on mid and short term level. The indicators which are most important to measure the achievement of the strategy (i.e. the strategic PI's) are also called Key Performance Indicators (KPI's).

Figure 19 shows the principle of performance measurement in Manufacturing Service Ecosystems. The individually agreed business strategy of the ecosystem is used to define goals on strategic, tactical and operational level. For each objective, decision variables can be defined that describe the actions performed to reach the objectives. The KPI's are selected to evaluate the effectiveness of those actions (see chapter 4).

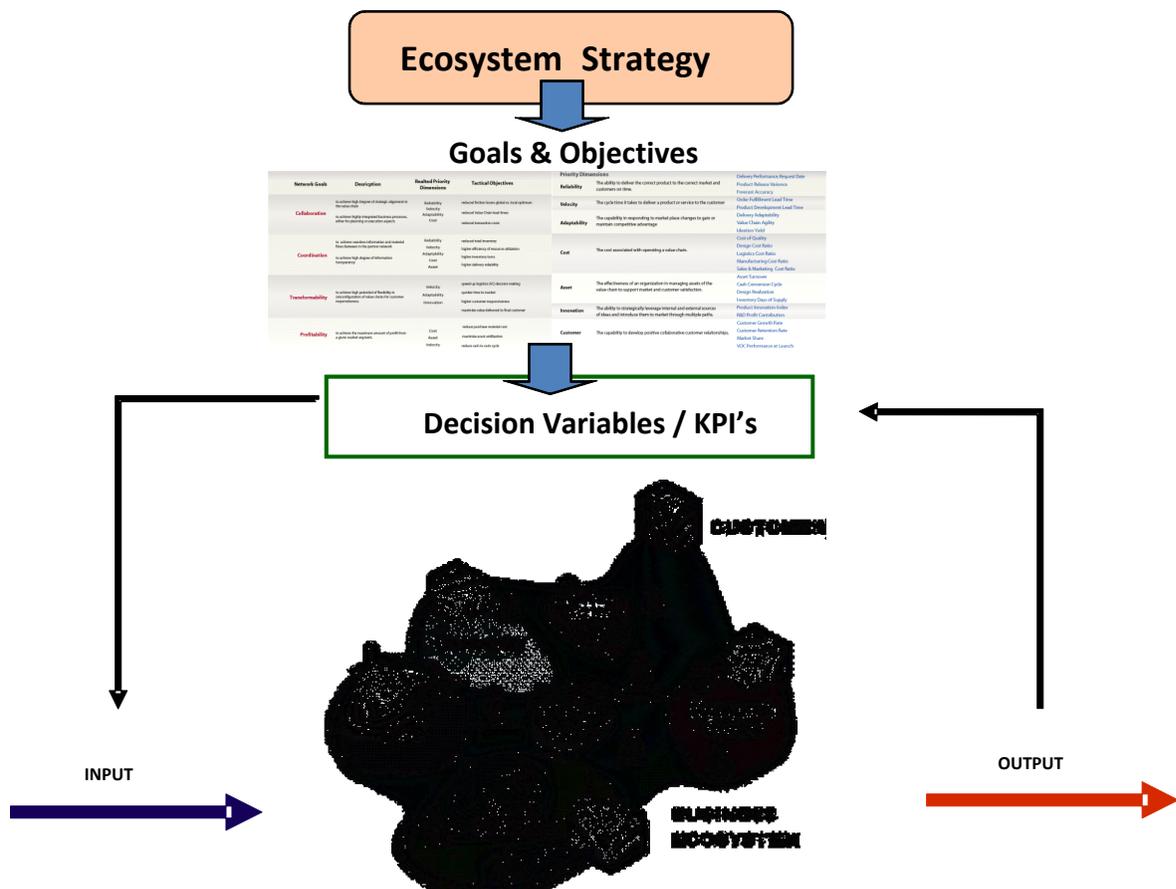
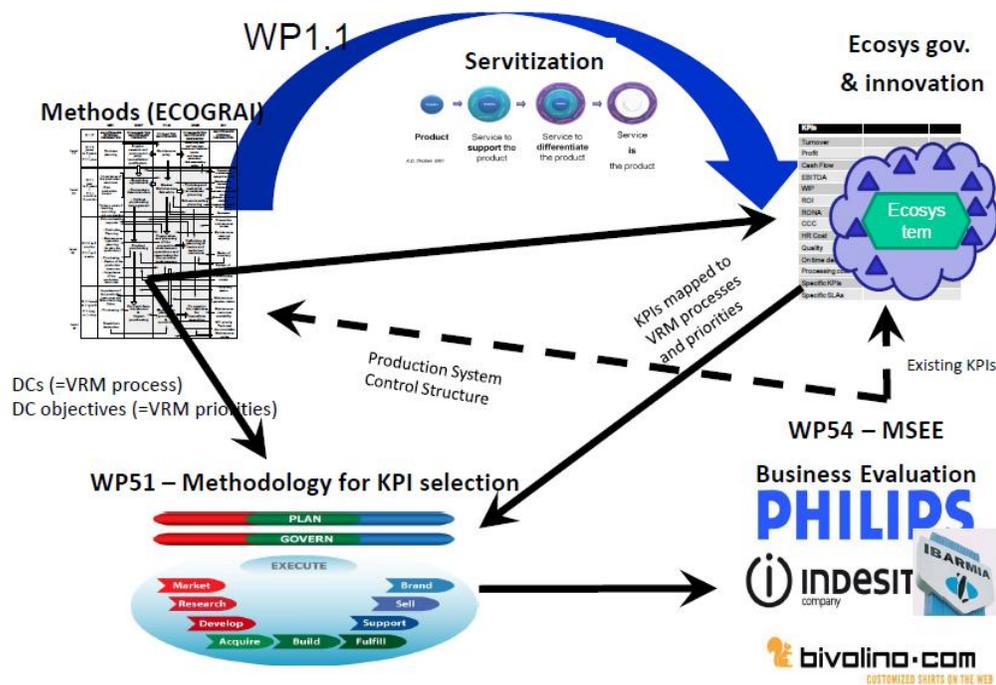


Figure 19: Principle of Performance Measurement in MSEE

The KPI Framework for MSEE is implemented by subprojects 1 and 5 and the associated work packages in the project. A definition of sets and methods to manage KPI's related to Manufacturing Service Ecosystems will be defined in conjunction. The interrelations between the components of the KPI Framework are shown in Figure 20.



**Figure 20: Implementation of KPI Framework in MSEE**

Based on the models determined in WP11 (UGF<sup>6</sup>, MDSEA<sup>7</sup>, ECOGRAI<sup>8</sup>), KPI's for Manufacturing Service Ecosystem governance are analyzed in terms of implementation and monitoring. Furthermore, a list of Decision Centers (DC) and DC objectives will be provided as input for the Methodology for KPI selection developed in WP51 (see chapter 4).

A harmonised list of KPI's for the different decision levels in MSEE, mapped to the Value Reference Model (VRM) processes and priorities used by the Methodology for KPI selection, is provided by WP13. It is based on existing KPI's from the four end-users and secondary research (see D13.1).

The Methodology for KPI selection is presented in this deliverable (see chapter 4). Developed in WP51, it is based on the Value Reference Model Framework, which provides pre-defined processes and indicators for the Value Chain. Using the Decision Centers and DC objectives provided by ECOGRAI and the list of KPI's defined by WP13, suitable KPI's can be selected for each of the four test cases.

Finally, the business evaluation of the MSEE is conducted in WP54 within the four end-user test cases. The KPI's selected using the methodology from WP51 are measured prior and after the implementation of the MSEE solutions. The difference will show improvements in the business processes evaluated.

The following sections will link the results of WP11 and WP13 with the development of the Methodology for KPI selection in this deliverable.

### 3.1. The ECOGRAI Method for Performance Indicator Systems

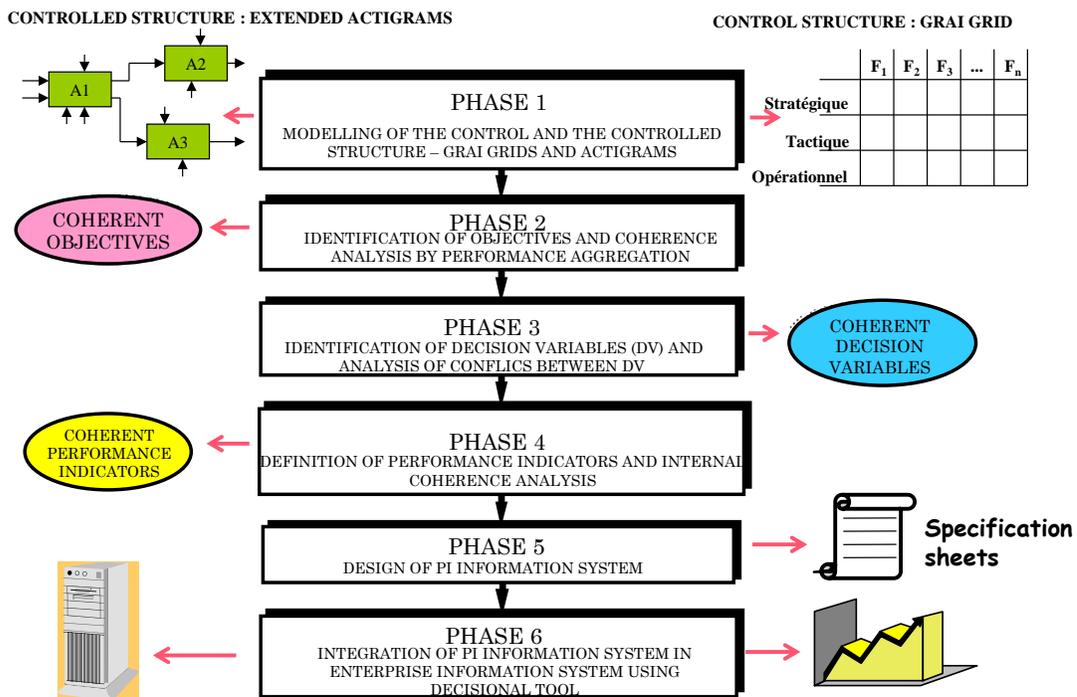
ECOGRAI is a method to design Performance Indicator Systems (PIS) for industrial and services organizations. It has been selected from the vast number of available methods to define and implement KPI's, because it is the only one based on decision modeling. Furthermore, the MSEE partner University of Bordeaux 1 has had experience with this

<sup>6</sup> Unified Governance Framework [Pfitzmann 2007]

<sup>7</sup> Model Driven Service Engineering Architecture

<sup>8</sup> ECOGRAI is a method proposed by GRAI to design and implement a system of PI's

method over 20 years with good results. It is described in detail in the deliverable D11.1. The ECOGRAI method is decomposed into six phases, which are depicted in Figure 21 below:



**Figure 21: The six Phases of ECOGRAI [MSEE D11.1]**

Each of the six phases produces a specific output, which will be further used in the KPI Framework for MSEE. The relevant outputs are described below, with a special focus on the usage for the Methodology for KPI selection:

- 1. Modeling of the business processes and identification of the Decision Centers:**  
 By modeling the organizational business processes and control structure, the Decisions Centers (DC) of the organization are identified. DC's are defined at a cross of the function and decision level in the GRAI grid/matrix.  
*Usage in the methodology for KPI selection: The DC's will serve as input to define the VRM processes for selection of the KPI's.*
- 2. Identification of the DC objectives and coherence analysis:**  
 Through identification of the organization's global objectives and the global objectives for each function in a top-down approach, the objectives of each DC are derived and checked for coherence.  
*Usage in the methodology for KPI selection: VRM priorities will be defined according to the identified DC objectives.*
- 3. Identification of the DC drivers and analysis of the conflicts:**  
 By evaluating the relationships inside and between the different functions, drivers corresponding to each objective of the DC's are identified.  
*Usage in the methodology for KPI selection: The DC drivers as input help to build relevant Performance Indicators in WP13 and include them into a coherent and comprehensive set of KPI's.*
- 4. Identification of the DC Performance Indicators and internal coherence analysis:**  
 Performance Indicators for each DC objective are identified using the knowledge of all stakeholders and checked for coherence.  
*Usage in the methodology for KPI selection: The identification of the KPI's in MSEE will be performed in WP54 according to the methodology defined in WP51, which*

uses the Decision Centers and DC objectives as input, as well as the set of indicators provided by WP13.

### 5. Design of Performance Indicator System (PIS):

The Performance Indicators are clearly defined with fundamental parameters for possible automation of the performance evaluation system.

*Usage in the methodology for KPI selection:* For each KPI, two aspects are considered: Which information is necessary and how is it processed? All indicators will be specified according to a common template.

### 6. Integration of the PIS inside MSEE:

The Performance Indicator System is integrated into the IT systems of the four MSEE test cases using the specification from phase 5.

*Usage in the methodology for KPI selection:* The integration of the Performance Indicator System inside MSEE will be supported by the MSEE solution to be developed.

The ECOGRAI method defines three working groups to implement the PIS: A synthesis group to define objectives and orientations and check the results of the analysis group, a functional group for the definition of the indicators for the function as well as an analysis group to help collect the information, organize meetings and propose solutions (see Figure 22).

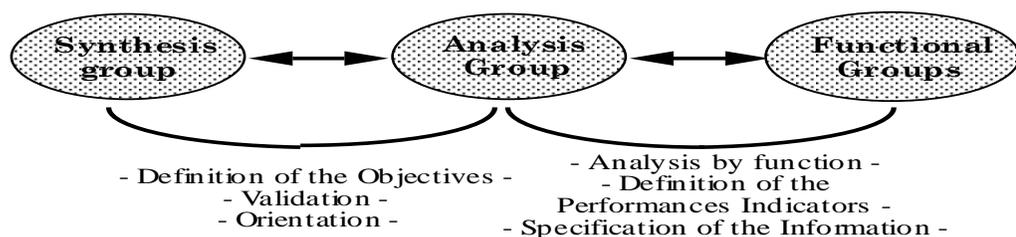


Figure 22: ECOGRAI Implementation Groups [MSEE D11.1]

In MSEE, the different groups will be composed of the following stakeholders to allow a seamless integration of the method into the project:

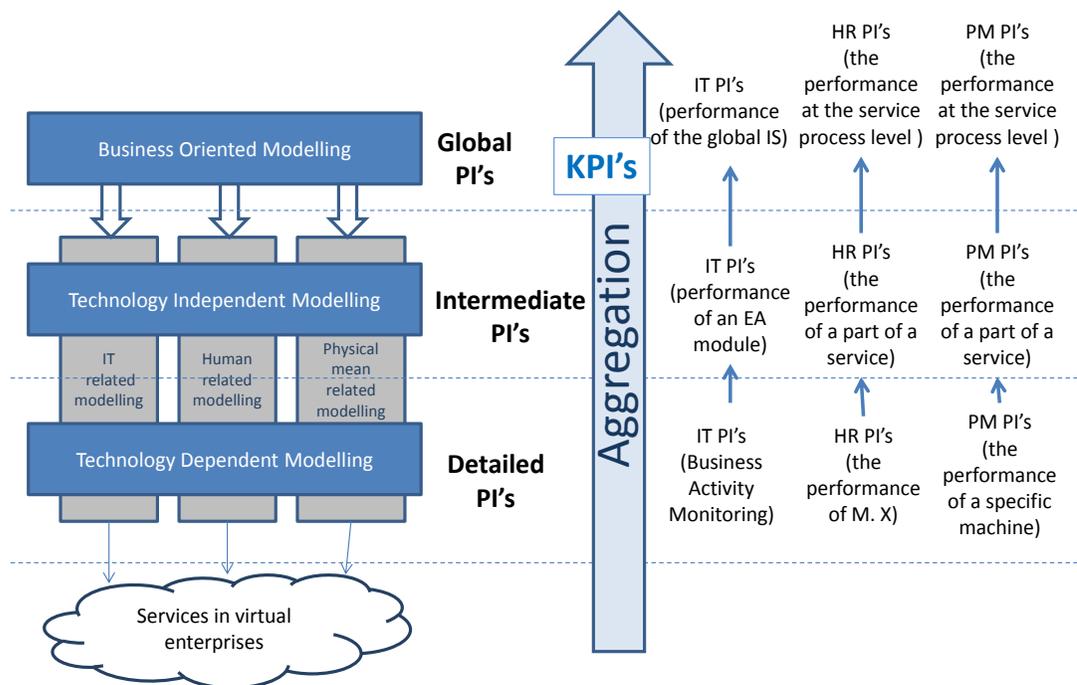
- Synthesis Group:**  
 The synthesis group will be represented by the MSEE coordination team, which will define the overall project objectives and check the results of WP54.
- Functional Group:**  
 The functional group will be formed from the partners in SP6 that prepare and run the demonstrations for the different functions of the four MSEE end-users.
- Analysis Group:**  
 The analysis group will consist of the partners in WP54, which is responsible for the measurement concept for verification and validation of industrial and business models.

### 3.2. Performance Indicators for Servitization

The innovative capacity of manufacturing companies can only be handled with a well developed innovation management focusing on product-related services. The performance of a company has to be measured before and after servitization to ensure that service processes act quickly, customer focused and flexibly.

The Model Driven Service Engineering (MDSE) architecture proposed in deliverable D11.1 describes three service modeling levels, for which different sets of KPI's are required (see

Figure 23). It is necessary to ensure that at each level performance evaluation is possible in order to verify the achievement of objectives.



**Figure 23: Performance Indicators in MDSE Levels [MSEE D11.1]**

The Business Oriented Modeling (**BOM**) level describes the enterprise and the ecosystem at a global level for the development of a service system. Performance indicators on this level will also be global and measure the performance of the complete service process. The measurement criteria defined at this level will be the same for the lower levels, but more detailed.

The second level of abstraction is described by Technology Independent Modeling (**TIM**), which is independent from the technology that will be used to implement the system. It focuses on the operation details, which is elaborated with respect to IT, human and physical means. The performance indicators on this level will also be detailed into the IT, human and physical dimension and are used to measure parts of a service or modules.

Technology Specific Modeling (**TSM**) constitutes the third level of abstraction and combines the TIM with details that specify the technology for the system. This refers to the development or acquisition of software, hardware, human resources or machines. TSM performance indicators are even more detailed than on TIM level and measure the performance of a process activity, a human resource or a machine.

A tool proposed in deliverable D13.1 to measure the level of servitization in a company is called InnoScore Service. It measures the innovative capacity of a company on the basis of nine organizational aspects:

- Strategy
- Innovation Culture
- Technology
- Process
- Products and Services
- Market
- Project Management
- Skills and Knowledge

- Structure and Network

### 3.3. Performance Indicators for Ecosystem Governance

Servitization, the shift from a product-centric to a service-centric view, requires a structured Performance Indicator System (PIS) as described in the previous sections. However, servitization does not only affect processes in a single company. The provision of Extended Products requires new industrial models, featuring collaboration between many different stakeholders. As being stated in the Factories of the Future PPP Strategic Multi-annual Roadmap [EC 2010] and implemented in the fifth MSEE objective:

*“Product/service systems will support the manufacturing industry in its transition towards providing customer value via product-linked services and solutions based on integrated product/service systems and the co-creation of value.”*

Therefore, the PIS will have to support performance measurement for the co-creation of value in collaborative environments. There have been approaches to implement performance measurement systems for hierarchical collaboration models in Supply Chain Management (SCM). SCM comprises *“the systematic, strategic coordination of the traditional business function and the tactic across these business functions within a particular company and cross business within the supply chain, for the purpose of improving the long – term performance of the individual companies and supply chain as whole”* [Gaiardelli 2007].

In this inter-organizational perspective, a PIS can help to support the coordination between the organizations inside the supply chain. The efficiency of the processes of the different actors has an impact on the overall supply chain performance. Their effectiveness can be measured in different dimensions (resources, output, flexibility) and on different levels (business, process, activity, innovation). However, the transformation of hierarchical supply chains into non-hierarchical business environments such as Manufacturing Service Ecosystems creates additional challenges for their governance:

- Lack of connection between strategy and measurement,
- biased focus on financial metrics,
- use of inappropriate measures,
- lack of system thinking.

To govern business processes and policies to support collaborative innovation in a secure industrial environment, the Unified Governance Framework (UGF) [Pfitzmann 2007] has been selected in D13.1. Purpose of the UGF is to distinguish and describe the components of enterprise governance on three layers:

- **Strategy layer:**  
Overall analysis of capabilities, goal setting, establishment of organizational structures.
- **Tactics layer:**  
Process, information and resource management, each corresponding to the strategy components.
- **Operations layer:**  
Day-to-day tasks evaluated according to the two above layers.

The combination of the UGF with the MDSE architecture (see section 3.2) leads to the decision making flow depicted in Figure 24 below:

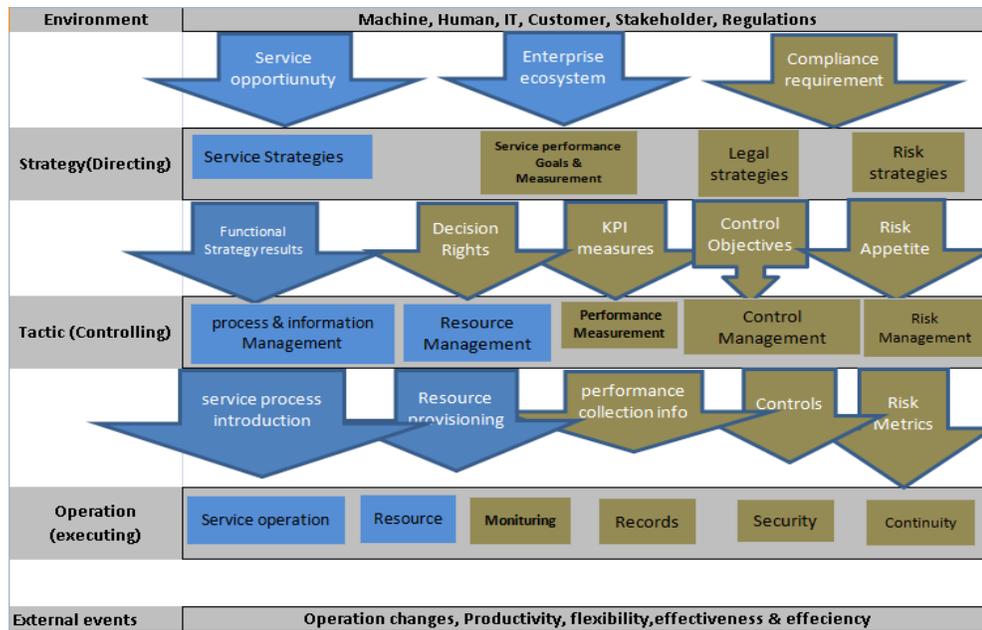


Figure 24: Downward Decision Flow between UGF Layers [D13.1]

However, decisions are influenced by information that is distributed between the layers of the UGF. At the bottom of the model, external events influence the operations layer and flow upwards towards the strategy layer, which in turn feeds back to the environment (see Figure 25):

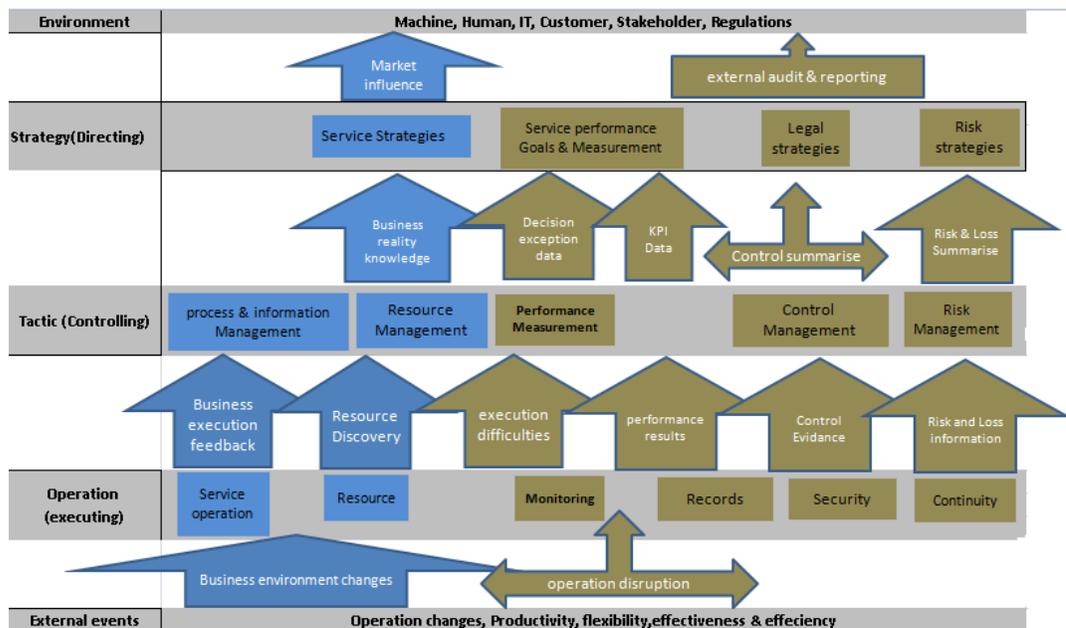
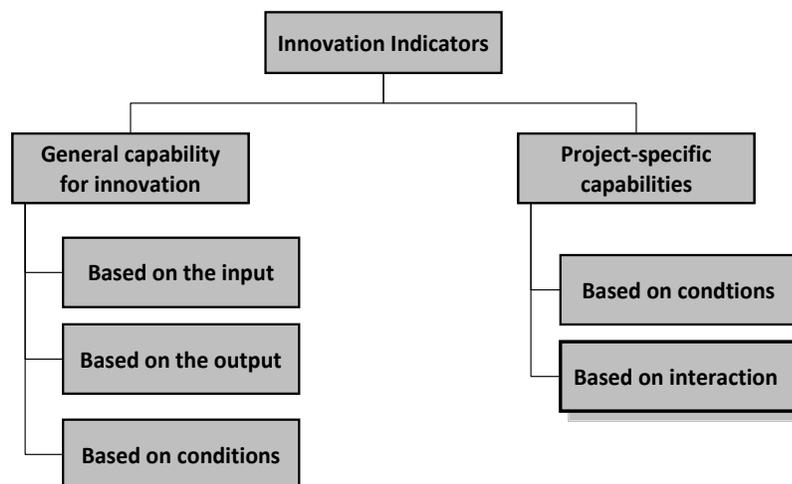


Figure 25: Upward Information Flow between UGF Layers [D13.1]

Thus, to deal with the governance of the ecosystem, the PIS will have to feature KPI's that enable the stakeholders to assess the performance of the organization with a link to the strategic objectives of the ecosystem. Therefore, the KPI's should be designed to track progress of the strategic objectives that have been defined. MSEE will use a dynamic UGF view with a top-down measuring model and a bottom up KPI analysis to create a PIS for the business evaluation within an MSE. The layers of the UGF are directly connected to the Plan, Govern and Execute levels of the Value Reference Model (VRM, see chapter 4) for selection of the indicators.

### 3.4. Performance Indicators for Service Innovation

Innovation is a critical success factor for the servitization of manufacturing. It is the foundation for the development of new services and the creation of Extended Products. Literature has already provided several suggestions for indicators that are related to innovation, however the existing set of PI regarding innovation is quite limited. Although there are various models to describe the innovation process, there is no approach with a related model for corresponding KPI's. However, different authors have suggested classifications for innovation indicators. A summary of the common elements is given in Figure 26 below:



**Figure 26: Classification of Innovation Indicators [D13.1]**

A typical indicator for the input for innovation processes is the R&D budget, while the number of patents and the profit share of new products are indicators for the output. Indicators for the performance of the innovation processes itself are e.g. the number of suggested ideas, the number of engineering changes or the number of contributors.

The set of KPI's for servitization, ecosystem governance and service innovation, which is created in WP13 will subsequently be used in the MSEE methodology for Business Evaluation. For each use case, adequate indicators will be selected according to the procedure described in the next chapter.

#### 4. Methodology for Business Evaluation

A Business Evaluation approach will be used to measure the business benefits of the Manufacturing Service Ecosystems for the end-user in order to achieve an improvement of process performance. The approach is based on the Value Reference Model (VRM) [VCG 2012], using performance indicators provided by WP13, e.g. through the Unified Governance Framework (UGF) [Pfitzmann 2007]. For each end user, specific project results will be implemented and used within their specific business processes.

The basis for the assessing of the ecosystem impact is the requirements of its users (identified in WP52). The capabilities of the Manufacturing Service Ecosystem are developed according to the desired changes in process parameters, on which they in return have an impact. The changed process parameters should lead to an improvement of process performance and thus finally to the expected business benefits (see Figure 27).

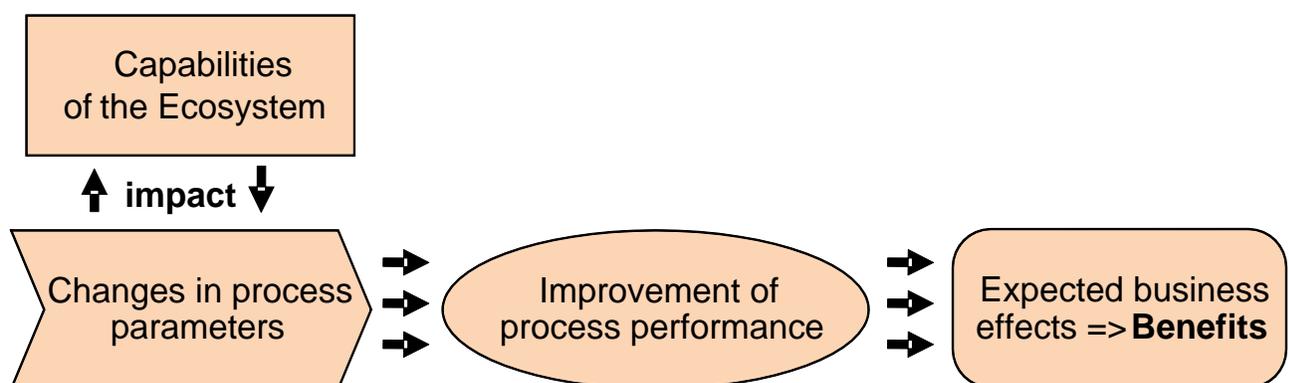


Figure 27: Ecosystem Benefits generated by Process Improvements

- Process *parameters* can be influenced directly by the organisation. These changes are enabled through functional capabilities provided by the ecosystem.
- Process *performance* received by customers and stakeholders is expected to be improved. The improvements represent goals that the end users want to achieve through the ecosystem and can be measured by corresponding performance indicators.
- The improvements lead to expected business effects, which are the anticipated *benefits* of the Manufacturing Service Ecosystem for the end users.

For the methodology used, the desired changes in process parameters are collected and process performance are measured following a reference model to validate the improvement by and thus the benefits for potential users. The approach links the end users with their products, services, processes, systems and the services provided by the Manufacturing Service Ecosystem in general. Measures for the improvement of business process performance help to align the strategic goals, services, products, customers and legacy systems of the partner with the specific applications and systems provided.

##### 4.1. Assessment of the MSEE Impact on Process Performance

A new methodology will be applied to assess and maximise the impact of the Manufacturing Service Ecosystem concept. It helps the end users to choose the right priorities out of the multiple dimensions of ecosystem benefits. Through state-of-the-art research and developments, suitable indicators for impact evaluation are selected. The specific indicators are measured prior and after the implementation of the ecosystem and allow its evaluation according to the user's requirements.

In MSEE, the Business Evaluation approach is based on the Value Reference Model (VRM) [VCG 2012], which provides pre-defined measurable indicators for Value Chain goals in several dimensions. Following this model, the MSEE end-user scenarios are used to select appropriate processes and dimensions, featuring the preferential goals and objectives for each end user. For each end user, internal tactical and operational priorities has been developed using the VRM. This allows selecting the appropriate Key Performance Indicators (KPIs), and measurement criteria to evaluate the tactical and operational improvements of implementing the MSEE system.

MSEE Business Evaluation will be performed using a 4-step approach to indicate MSEE benefits for the end-users. The following actions are performed during the steps:

1. Selection of **VRM Processes**, based on scenarios and the expected benefits through MSEE.
2. Definition of **VRM Priority Dimensions** (*Adaptability, Assets, Cost, Customer, Innovation, Reliability, Velocity*) for each process or combination of processes.
3. Usage of the VRM Framework for **Identification of KPI's** according to selected processes and priorities.
4. **Measurement** of AS-IS situation/processes before using the MSEE Services. The users will also name the expected improvements through MSEE. Measurement of situation/processes after using MSEE. The *difference/delta* will give an indication for business benefits and verification in using MSEE.

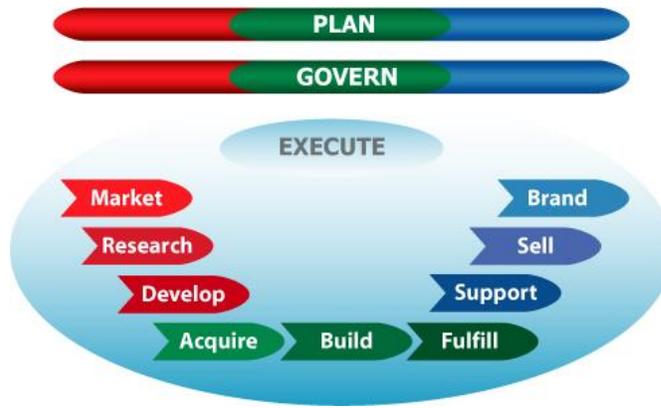
## 4.2. The Value Reference Model Framework

The VRM model is structured to support the integration of the three domains product development, the supply chain and customer relation in a reference model for an integrated value chain. It provides descriptions of standard processes, their inputs and outputs, *metrics* and best practices. Input and output templates and guidelines for tactical level processes are also provided. The VRM does not only focus solely on managing the processes of a supply chain for a given product, but also incorporates the preceding and successive activities of product development and customer relations in the sense of a value chain. By application of the VRM, value chain goals of horizontal and vertical collaboration are supported by a standardised “language” of syntax and semantics. Processes, activities and their dependencies are described and relational connected throughout the value chain. The comprehensiveness of the Value Reference Model provides a suitable approach for *visualization of the performance(s)* of the total Value Chain, or parts thereof by providing *standard metrics (Key Performance Indicator's)* throughout the Value Chain [VCG 2012].

### 4.2.1. VRM Processes

The Top Level of the model encompasses all the high level processes in Value Chains which are represented through the Process Categories *Plan – Govern – Execute* (see Figure 28). The Plan process is used to align strategic objectives with tactical and execution abilities. Govern supports the strategic objectives by rules, policies and procedures for the Value Chain. Execute encompasses all execution processes in a strategic context within the management criteria from Govern and the parameters defined by Plan.

The Level is defined to be the Strategic Level of the Model, meaning that this is where high level decisions are made regarding how to gain a competitive advantage for the Value Chain in scope. An example of such a competitive advantage could be Increased Market Share through a Cost Optimized, Adaptive Value Chain and extensive Collaboration with Customers and/ or network partners [VCG 2012].



**Figure 28: VRM Strategic and Tactical Level Processes [VCG 2012]**

The Second level of the model contains “abstract” processes decomposed from the Strategic Level. The Value Reference Model processes decompose from Strategic to the Tactical Level with Plan and Govern keeping their respective naming. Execute decomposes to *Market-Research-Develop-Acquire-Build-Sell-Fulfill-Support* [VCG 2012].

The third level of the model represents specific processes in the value chain related to actual activities being executed. On this level, focus is usually vertical business process improvements or business process re-engineering as many name it (see Figure 29). In a value chain perspective this is the level where fine-tuning occurs [VCG 2012]. Thus, performance measurement on this level is key to evaluate the improvements by using the MSEE services and assessing the benefits.

PLAN					GOVERN										
Plan Value Chain	PV1 Gather Value Chain Requirements	PV2 Assess Value Chain Resources	PV3 Align Value Chain Resources	PV4 Create Value Chain Plan	Govern Value Chain	GV01 Set Strategy & Vision	GV02 Set Performance Policy	GV03 Set Information Policy	GV04 Set Financial Policy	GV05 Set Asset Policy	GV06 Set Social & Ethical Policy	GV07 Set Network Policy	GV08 Set Change Guidelines	GV09 Set Compliance Policy	GV10 Set Life Cycle Policy
Plan Product Development	PP1 Gather Product Development Requirements		PP2 Assess Product Development Resources		Govern Product Development	GP01 Govern Product Development Rules		GP02 Govern Product Development Process		GP03 Govern Product Development Information		GP04 Govern Product Development Finance		GP05 Govern Product Development Assets	
	PP3 Align Product Development Resources		PP4 Create Product Development Plan			GP06 Govern Product Development Personnel		GP07 Govern Product Development Network		GP08 Govern Product Development Change		GP09 Govern Product Development Compliance		GP10 Govern Product Development Life Cycle	
Plan Supply Chain	PS1 Gather Supply Chain Requirements		PS2 Assess Supply Chain Resources		Govern Supply Chain	GS01 Govern Supply Chain Rules		GS02 Govern Supply Chain Process		GS03 Govern Supply Chain Information		GS04 Govern Supply Chain Finance		GS05 Govern Supply Chain Assets	
	PS3 Align Supply Chain Resources		PS4 Create Supply Chain Plan			GS06 Govern Supply Chain Personnel		GS07 Govern Supply Chain Network		GS08 Govern Supply Chain Change		GS09 Govern Supply Chain Compliance		GS10 Govern Supply Chain Life Cycle	
Plan Customer Relations	PC1 Gather Customer Relations Requirements		PC2 Assess Customer Relations Resources		Govern Customer Relations	GC01 Govern Customer Relations Rules		GC02 Govern Customer Relations Process		GC03 Govern Customer Relations Information		GC04 Govern Customer Relations Finance		GC05 Govern Customer Relations Assets	
	PC3 Align Customer Relations Resources		PC4 Create Customer Relations Plan			GC06 Govern Customer Relations Personnel		GC07 Govern Customer Relations Network		GC08 Govern Customer Relations Change		GC09 Govern Customer Relations Compliance		GC10 Govern Customer Relations Life Cycle	
EXECUTE															
Market	Research	Develop	Acquire	Build	Fulfill	Brand	Sell	Support							
M1 Analyze Market	R1 Define Opportunity	D1 Define Product Req	A1 Qualify Supplier	B1 Schedule Resource	F1 Order Inquiry	N1 Define Brand Req	S1 Target Customer	U1 Register Customer							
M2 Analyze Performance	R2 Forecast Technology	D2 Select Technology	A2 Issue Request	B2 Issue Material	F2 Confirm Order	N2 Differentiate Brand	S2 Qualify Target	U2 Manage Incident							
M3 Define Need	R3 Acquire Technology	D3 Design Product	A3 Evaluate Proposal	B3 Build Product	F3 Plan Load	N3 Select Market Channels	S3 Position Solution	U3 Resolve Problem							
M4 Architect Solution	R4 Define New Technology	D4 Design Process	A4 Negotiate Contract	B4 Verify Product	F4 Receive Warehouse	N4 Architect Brand	S4 Develop Relationship	U4 Process Return							
M5 Develop Case	R5 Validate Technology	D5 Validate Product	A5 Place Order	B5 Package Product	F5 Fill Order	N5 Validate Brand	S5 Assess Need	U5 Educate Customer							
M6 Validate Opportunity	R6 Protect Technology	D6 Align Supply Chain	A6 Receive Order	B6 Stage Product	F6 Ship Order	N6 Protect Brand	S6 Develop Proposal	U6 Deliver Service							
M7 Product Roadmap	R7 Transfer Technology	D7 Define Product Lifecycle	A7 Verify Order	B7 Release Product	F7 Deliver Order	N7 Assess Supply Network	S7 Present Proposal	U7 Monitor Experience							
	R8 Introduce Technology	D8 Launch Product	A8 Transfer Inventory	B8 Verify Product	F8 Verify Receipt	N8 Create Marketing Roadmap	S8 Finalize Contract								
			A9 Authorize Payment		F9 Install & Test	N9 Launch Brand	S9 Review Win / Lost								
					F10 Invoice										

**Figure 29: VRM Operational Level Processes [VCG 2012]**

#### 4.2.2. VRM Priority Dimensions

The metrics provided by VRM are not only mapped to the processes of the framework, but also grouped into seven distinct dimensions, each representing a different area for optimization (see Table 3). For the evaluation of the MSEE system, indicators from each priority dimension have been selected to show the global nature of benefits that can be achieved with the MSEE system.

Table 3: VRM Priority Dimensions [VCG 2012]

Priority Dimension	Description	Examples for KPI's
<b>Reliability</b>	The ability to deliver the correct product to the correct market and customers on time.	<i>Delivery Performance, Request Date, Product Release Variance, Forecast Accuracy</i>
<b>Velocity</b>	The cycle time it takes to deliver a product or service to the customer.	<i>Order Fulfillment Lead Time, Product Development Lead Time</i>
<b>Adaptability</b>	The capability in responding to market place changes to gain or maintain competitive advantage.	<i>Delivery Adaptability, Value Chain Agility, Ideation Yield</i>
<b>Cost</b>	The cost associated with operating a value chain.	<i>Cost of Quality, Design Cost Ratio, Logistics Cost Ratio, Manufacturing Cost Ratio, Sales &amp; Marketing Cost Ratio</i>
<b>Asset</b>	The effectiveness of an organization in managing assets of the value chain to support market and customer satisfaction.	<i>Asset Turnover, Cash Conversion Cycle, Design Realization, Inventory Days of Supply</i>
<b>Innovation</b>	The ability to strategically leverage internal and external sources of ideas and introduce them to market through multiple paths.	<i>Product Innovation Index, R&amp;D Profit Contribution</i>
<b>Customer</b>	The capability to develop positive collaborative customer relationships.	<i>Customer Growth Rate</i>

#### 4.2.3. VRM Metrics

After processes and priority dimensions have been identified for each of the MSEE end-users, the VRM gives information about possible metrics to measure business process improvements. Table 4 shows the information delivered for each metric by the VRM.

Table 4: VRM Metric Information

Information	Content
<b>Metric Name</b>	Brief descriptive name less than 50 characters.

<b>Metric Definition</b>	Detailed definition usually one sentence to two paragraphs in length.
<b>Priority Dimensions</b>	Strategic Classifications used in Value Chain Alignment.
<b>Metric Class &amp; Sub Class</b>	Classification for navigation and search index.
<b>Formula</b>	Algorithm for calculating metric value. Some metrics are considered a „Base Metric“ in which calculations are not required.
<b>Input Requirements</b>	Suggested application data fields and sources to acquire information necessary for performing the calculation.
<b>Dimensions</b>	Sources of input from different areas of involvement.
<b>Calculation Rules</b>	General notes and guidelines for use of the metric.

### 4.3. Selection and Measurement of Metrics for the MSEE End-Users

The selection and measurement of metrics for the various test cases in MSEE follows the methodology for business evaluation described above. It is structured into four distinct steps, related to methodology:

#### 1. Selection of VRM Processes

The MSEE business use cases (BUCs) describe the concrete interactions of the users from the test cases influenced by the MSEE system. They are used to specify how exactly the innovative tools and services help users in performing and improving their current business processes. BUCs selected by the expected degree of influence by MSEE have been analysed together with MSEE end users and translated into the corresponding VRM processes.

#### 2. Definition of VRM Priority Dimensions

According to the selected VRM processes, various dimensions of improvement are available. The end users have to identify, which priority dimensions are most important for their specific use case, respectively in which area they want to achieve business improvement while using the MSEE services. The VRM priority dimensions will be selected for each process or group of processes accordingly.

#### 3. Identification of KPI's

From the selected processes and priority dimensions, the VRM provides a list of suggested metrics for the measurement of improvements. However, this list neither claims to be complete nor exclusive. There is the possibility to add other KPI's.

#### 4. Measurement of Process Improvements

The identified KPI's are measured within the respective business processes by the end users before and after implementation of MSEE services. The users will also name the expected improvements through MSEE. The difference or delta between the measurements will give an overview of the improvements effected by the services. By using KPI's from different priority dimensions, the benefit of MSEE of a global nature can be validated.

## 5. Summary and Conclusions

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This deliverable has had the purpose to present the results of MSEE task T51.2 “Defining a novel concept for requirements engineering & evaluation”. Therefore, a specific requirements engineering and evaluation methodology for Manufacturing Service Ecosystems has been developed.

In the first chapter, the function of WP51 in MSEE and its position in the project context is explained. Based on this classification, the objectives of D51.2 and the structure of the deliverable are described.

The second chapter defines the methodology for Requirements Engineering in MSEE. Based on the analysis of existing approaches for requirements elicitation from D51.1, the implications for requirements elicitation, analysis, specification and validation in MSEE are derived and the methodology is developed on the basis of Serious Gaming and Service Modeling.

Chapter 3 introduces the concepts for Performance Indicators in Manufacturing Service Ecosystems from SP1 as background for the MSEE business evaluation. Initially, the ECOGRAI method for the design of Performance Indicator Systems is described. In the following sections, the Performance Indicator framework for servitization, ecosystem governance and service innovation is presented.

In Chapter 4, the methodology for MSEE business evaluation is given. The principle for the assessment of the MSEE impact on process performance is explained and the Value Reference Model is introduced. Finally, the procedure for selection of indicators for the different end-users is presented.

As a conclusion, D51.2 develops a new methodology for Requirements Engineering, based on Serious Gaming and Service Modeling which can be applied in the Manufacturing Service Ecosystem context of the project. Furthermore, the methodology to evaluate the business benefits resulting from the MSEE developments based on specific Performance Indicators and the Value Reference Model is defined. Thus, this deliverable provides a comprehensive reference for specifying and evaluating the developments inside the project.

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