



SATISFACTORY



SATISFACTORY

Project Acronym: **SatisFactory**
 Project Full Title: **A collaborative and augmented-enabled ecosystem for increasing satisfaction and working experience in smart factory environments**
 Grant Agreement: **636302**
 Project Duration: **36 months (01/01/2015 - 31/12/2017)**

DELIVERABLE D1.2

Use Case Analysis and Application Scenarios Description

Deliverable Status: **Final**
 File Name: **SatisFactory-D1.2-v3.pdf**
 Due Date: **March 2017 (M27)**
 Submission Date: **March 2017 (M27)**
 Deliverable Leader: **SUNLIGHT**

Dissemination level	
Public	X
Confidential, only for members of the Consortium (including the Commission Services)	



This project has received funding from the European Union's Horizon 2020 Research and innovation programme under Grant Agreement n°636302

The SatisFactory project consortium is composed of:

CERTH¹	Centre for Research and Technology Hellas	Greece
SIGMA²	Sigma Orionis SA	France
FRAUNHOFER	Fraunhofer-Gesellschaft zur Foerderung der Angewandten Forschung E.V	Germany
COMAU	Comau SPA	Italy
EPFL	Ecole Polytechnique Fédérale de Lausanne	Switzerland
ISMB	Istituto Superiore Mario Boella sulle tecnologie dell'informazione e delle telecomunicazioni	Italy
ABE	Atlantis Engineering AE	Greece
REGOLA	Regola srl	Italy
SUNLIGHT	Systems Sunlight Industrial & Commercial Company of Defensive, Energy, Electronic and Telecommunication Systems S.A.	Greece
GlassUP	GlassUp srl	Italy
QPLAN	Q-PLAN International Advisors LTD	Greece

Disclaimer

This document reflects only the author's views and the European Union is not liable for any use that may be made of the information contained therein.

¹ Project Coordinator

² Terminated beneficiary since June 2016 and replaced by QPLAN

AUTHORS LIST

Leading Authors (Editors)				
Surname		First Name	Beneficiary	Contact email
Parcharidis		Symeon	SUNLIGHT	s.parcharidis@sunlight.gr
Ziougou		Chrysovalantou	CERTH	czougou@cperi.certh.gr
Co-authors (in alphabetic order)				
#	Surname	First Name	Beneficiary	Contact email
1	Brizzi	Paolo	ISMB	brizzi@ismb.it
2	Cultrona	Pietro Alberto	COMAU	Pietro.cultrona@comau.com
3	Della Casa	Emiliano	GlassUp	emiliano.dellacasa@glassup.net
4	Effraimidis	Georgios	ATLANTIS	ge@abe.gr
5	Elmasllari	Erion	FIT	erion.elmasllari@fit.fraunhofer.de
6	Elsianli	Katerina	ATLANTIS	elsianli@abe.gr
7	Giartosio	Francesco	GlassUp	francesco@glassup.net
8	Ippolito	Massimo	COMAU	MASSIMO.IPPOLITO@comau.com
9	Jentsch	Marc	FIT	marc.jentsch@fit.fraunhofer.de
10	Kanidis	Stefanos	Sunlight	s.kanidis@sunlight.gr
11	Metaxa	Ifigeneia	ATLANTIS	metaxa@abe.gr
12	Nunzio	Damiano	EPFL	Damiano.arena@epfl.ch
13	Rusinà	Fulvio	COMAU	Fulvio.rusina@comau.com
14	Serra	Antonio	Regola	a.serra@regola.it
15	Sottile	Francesco	ISMB	sottile@ismb.it
16	Turinetto	Maurizio	Regola	m.turinetto@regola.it
17	Vergori	Paolo	ISMB	vergori@ismb.it
18	Vlachogiannis	Evangelos	FIT	evangelos.vlachogiannis@fit.fraunhofer.de
19	Voutetakis	Spyros	CERTH	paris@cperi.certh.gr

REVISION CONTROL

Version	Author	Date	Status
2.1	CERTH	February 2017	Initial Draft
2.2	CERTH	February 2017	ToC Revision
2.3	CERTH	February 2017	Revision of CERTH Business Scenarios
2.4	ISMB	March 2017	Use Cases Revision of ISMB
2.5	Regola	March 2017	Changes regarding the description of the presentation tool of Regola
2.6	Sunlight	March 2017	Revision of Sunlight Business Scenarios
2.7	CERTH	March 2017	Addition of the 7.3 paragraph with the description of the response strategies
2.75	EPFL	March 2017	Revision of Use Cases related to ontology manager
2.8	CERTH	March 2017	Addition of 5.6 paragraph
2.9	CERTH	March 2017	Draft version, sent to partners for review
3.0	Sunlight/ CERTH	March 2017	Ready for submission to the EC

REVIEWERS LIST

List of Reviewers (in alphabetic order)				
#	Surname	First Name	Beneficiary	Contact email
1	Serra	Antonio	Regola	a.serra@regola.it
2	Sottile	Francesco	ISMB	sottile@ismb.it
3	Turinetto	Maurizio	Regola	m.turinetto@regola.it
4	Vergori	Paolo	ISMB	vergori@ismb.it

TABLE OF CONTENTS

List of Figures	9
List of Tables	13
List of Definitions & Abbreviations.....	16
Executive Summary	17
1 Introduction	18
1.1 Purpose, Context and Scope of this Deliverable.....	18
1.2 Background.....	19
1.3 Document Structure	20
2 Review of the existing standards for analysing the actual actors and procedures	22
2.1 Business Process Management / Workflow Management.....	22
2.1.1 Introduction.....	23
2.1.2 BPM Lifecycle	23
2.1.3 SatisFactory Scope.....	24
2.2 Modelling Standards	24
2.2.1 Business Process Modelling Notation (BPMN).....	25
2.2.2 Petri Nets.....	25
2.2.3 Yet Another Workflow Language - YAWL.....	26
2.2.4 Unified Modelling Language - UML.....	26
2.2.5 Event-Driven Process Chains - EPC.....	26
2.3 Execution Standards.....	27
2.3.1 XLANG and WSFL	27
2.3.2 Business Process Execution Language – BPEL	27
2.3.3 BPEL for People	28
2.3.4 Business Process Management Language - BPML.....	28
2.4 Modelling Tools	29
2.4.1 YAWL System.....	29
2.4.2 Modelio Open Project	30
2.4.3 Intalio bpm Community Edition	30
2.4.4 Visual Paradigm for UML Community Edition	32
2.4.5 Microsoft Visio.....	32
2.5 Comparison of standards and tools.....	33
2.5.1 Comparison of Tools.....	34
2.6 Selection of Modelling approach for the SatisFactory project.....	35
3 Role Based Procedures analysis	36
3.1 Classification and Clustering of Procedures	37
3.1.1 Type of process.....	38
3.1.2 Involvement of personnel (actors)	38
3.1.3 Classification of procedures	39
3.1.4 Classification on the basis of the macro activities membership	39
3.1.5 Classification based on the type of functions associated with.....	40
3.1.6 Classification based on the type of "triggering"	41
3.2 Special Needs and Requirements	41

3.2.1	Translation of the Procedures	42
3.2.2	Specific requirements related to the translation of the original procedures	43
3.2.3	Requirements of "guidelines" to be used in collecting relevant data	43
3.2.4	Requirements of "formalism" to be used for the translation of original procedures	44
3.2.5	Presentation of the Procedures	44
3.2.6	Requirements related to the environment	45
3.2.7	Example of a Standard Operation Procedure.....	45
4	Actors and Procedures	47
4.1	Definition of methodology for Actors Analysis.....	48
4.2	Multi Actor Multi Criteria Analysis	48
4.2.1	SatisFactory Main Categories of Actors.....	50
4.2.2	Template for definition of Actors	51
4.3	High Level Procedure Description	51
4.4	SatisFactory Actors.....	55
4.4.1	Actors of COMAU's shop floor	55
4.4.2	Actors of SUNLIGHT's shop floor	57
4.4.3	Actors of CERTH/CPERI's shop floor	64
4.4.4	Connection of Actors with Application Scenarios & Use Cases.....	69
5	SatisFactory Business Scenarios.....	72
5.1	Template for Application Scenarios.....	74
5.2	Business Scenarios at Automotive Manufacturing shop floor (COMAU).....	76
5.2.1	BSC-1 - Operation activities of machine assembly at manufacturing procedures (COMAU)...	76
5.2.2	BSC-2 - Support of the components of production lines for intermittent operation (COMAU)	81
5.2.3	Progress on the Business Scenarios in automotive manufacturing shop floor	83
	Activities performed in COMAU business scenarios so far consist in two steps:	84
5.3	Business Scenarios at Batteries Manufacturing shop floor (SUNLIGHT).....	89
5.3.1	BSC-3 Knowledge enabled support of systems and workforce for semi-automated battery assembly lines (SUNLIGHT)	90
5.3.2	BSC-4 Monitoring and learning activities at battery production lines (SUNLIGHT)	92
5.4	Business Scenarios at Chemical Processes shop floor (CERTH)	98
5.4.1	BSC-5 Online supervision of the operation and workforce resources of pilot plants for chemical processes (CERTH)	99
5.4.2	BSC-6 Recognition of incidents regarding workers' movement (CERTH).....	110
5.5	Role of SatisFactory for selected operations at a shop floor with pilot plants for chemical processes	112
5.6	Implementation of the Application Scenarios.....	114
6	Use Cases Development – Methodology and Models	115
6.1	Methodology for Use Case information gathering	116
6.1.1	Generic Description of Use Cases.....	117
6.2	Template for Use Cases	118
6.3	Modelling of Use Cases.....	119
6.3.1	UML - Use Case Diagrams.....	119
6.4	SatisFactory Use Cases	121
6.4.1	Selection Methodology and Definition of Use Cases	121



6.5	SatisFactory Use Case Analysis.....	122
6.5.1	UC-1 Data aggregation and analysis from heterogeneous sources at the shop floor.....	124
6.5.2	UC-2 Learning environment with interactive training activities for multi-purpose operations	132
6.5.3	UC-3 Dynamic utilization of augmented intelligence with intuitive information presentation	140
6.5.4	UC-4 Intelligent decision support and maintenance for increased flexibility	150
6.5.5	UC-5 Collaboration and social interaction for increased workers' engagement	162
6.5.6	UC-6 Presentation of activities and bidirectional communication for enhanced shop floor feedback.....	171
7	Assessment of Application Scenarios, Use Cases and Requirements	181
7.1	Application Scenarios connection to the User Needs and Requirements.....	181
7.1.1	Application Scenarios and Use Cases	184
7.1.2	Application Scenarios and involved Actors	186
7.2	Connection of Application Scenarios with the project objectives.....	186
7.2.1	Priorities of Application Scenarios for deployment	188
7.3	Response strategies at SatisFactory	188
7.3.1	Response Strategies to Shop floor Incidents/Events at COMAU shop floor	189
7.3.2	Response Strategies to Shop floor Incidents/Events at Sunlight shop floor	189
7.3.3	Response Strategies to Shop floor Incidents/Events at CERTH/CPERI shop floor.....	190
7.3.4	Summary of the Response Strategies at SatisFactory	190
8	Conclusions.....	192
	References	193
	Annex 1 – Detailed Main Flow Of Application Scenarios	194
	Annex 2 – Requirements Description	204
	Annex 3 – Description of the Architecture Components.....	207
	Annex 4 – Modeling Standards	213

LIST OF FIGURES

Figure 1 Activities and Connection of D1.2 with other tasks and WPs	19
Figure 2 Content and Activities of Chapter 2	22
Figure 3 BPM Lifecycle.....	24
Figure 4 Control-flow specification in YAWL Editor	30
Figure 5 Intalio bpms Designer screenshot	31
Figure 6 UML Sequence Diagram designed in Visual Paradigm	32
Figure 7 Microsoft Visio screenshot.....	33
Figure 8 Content and Activities of Chapter 4	36
Figure 9 Standard Operation Procedure generic steps	37
Figure 10 Content and Activities of Chapter 3	47
Figure 11 Definition of the modelling methodology for analysing the actual actors and procedures of the shop floor	48
Figure 12 Steps to define the actors at the shop floors	49
Figure 13 Actor Category – Managers and Engineers	50
Figure 14 Actor Category – Supervisors	50
Figure 15 Actor Category – Operators and Technicians.....	50
Figure 16 Breaking down the procedure description of the use case.....	52
Figure 17 Categorisation of procedure types.....	53
Figure 18 Workflow diagram.....	54
Figure 19 COMAU’s Actors’ interconnection diagram	55
Figure 20 SUNLIGHT’s Actors’ interconnection diagram.....	58
Figure 21 CERTH/CPERI’s Actors’ interconnection diagram.....	64
Figure 22 Hierarchy of Business Scenarios and Application Scenarios per end user	74
Figure 23 COMAU Robot	77
Figure 24 COMAU Final assembly of the robot arm.....	77
Figure 25 COMAU Welding gun.....	79
Figure 26 COMAU welding gun body assembly (a)	79
Figure 27 COMAU Welding gun body.....	79
Figure 28 COMAU working environment	81
Figure 29: Implementation Roadmap	84
Figure 30: Robot wrist	84
Figure 31: Innovative workplace concept	85

Figure 32: Innovative workplace 1 st implementation hypothesis	86
Figure 33: Innovative workplace 2 nd implementation hypothesis	86
Figure 34: Innovative workplace 3 rd implementation hypothesis.....	87
Figure 35: Digital caliper.....	87
Figure 36: Digital micrometer	87
Figure 37: Digital dial.....	88
Figure 38: Digital force gauge.....	88
Figure 39: Digital torque wrench.....	88
Figure 40: Augmented reality platform interface	89
Figure 41 Maintenance procedure at SUNLIGHT	90
Figure 42 Battery assembly procedure at SUNLIGHT.....	92
Figure 43 Battery assembly technical drawings	93
Figure 44 SUNLIGHT Jar formation units.....	95
Figure 45 SUNLIGHT manual temperature monitoring procedure	95
Figure 46 SUNLIGHT roadmap for Business Scenarios	98
Figure 47 An example of live data of the status of the pilot plant.....	100
Figure 48 Part of a reactor, including a heating resistance at CERTH/CPERI	100
Figure 49 The loaded feed tank of a CERTH/CPERI pilot plant.....	104
Figure 50 Creating a solution package	107
Figure 51 Change operation conditions to the pilot plant through a solution package	107
Figure 52 Flow diagram from a pilot plant at CERTH	108
Figure 53 Movement tracking at CERTH/CPERI's shop floor through normal camera	110
Figure 54 Movement tracking at CERTH/CPERI's shop floor through depth camera	110
Figure 55 Roadmap for implementation of CERTH/CPERI scenarios	113
Figure 56 Content and Activities of Chapter 6	115
Figure 57 Use Case Determination.....	116
Figure 58 An example of Use Case diagram	120
Figure 59 High-level Use Case diagram	123
Figure 60 Analysis of UC-1.....	124
Figure 61 Analysis of UC-1.1.....	126
Figure 62 Relationship of UC-1.1 with other UCs and BSCs	126
Figure 63 Analysis of UC-1.2.....	128
Figure 64 Relationship of UC-1.2 with other UCs and BSCs	129
Figure 65 Analysis of UC-1.3.....	131
Figure 66 Relationship of UC-1.3 with other UCs and BSCs	131

Figure 67 Analysis of UC-2.....	132
Figure 68 Analysis of UC-2.1.....	134
Figure 69 Relationship of UC-2.1 with other UCs and BSCs	134
Figure 70 Analysis of UC-2.2.....	136
Figure 71 Relationship of UC-2.2 with other UCs and BSCs	137
Figure 72 Analysis of UC-2.3.....	139
Figure 73 Relationship of UC-2.3 with other UCs and BSCs	140
Figure 74 Analysis of UC-3.....	141
Figure 75 Analysis of UC-3.1.....	143
Figure 76 Relationship of UC-3.1 with other UCs and BSCs	144
Figure 77 Analysis of UC-3.2.....	146
Figure 78 Relationship of UC-3.2 with other UCs and BSCs	146
Figure 79 Analysis of UC-3.3.....	148
Figure 80 Relationship of UC-3.3 with other UCs and BSCs	148
Figure 81 Analysis of UC-3.4.....	150
Figure 82 Relationship of UC-3.4 with other UCs and BSCs	150
Figure 83 Analysis of UC-4.....	151
Figure 84 Analysis of UC-4.1.....	153
Figure 85 Relationship of UC-4.1 with other UCs and BSCs	153
Figure 86 Analysis of UC-4.2.....	155
Figure 87 Relationship of UC-4.2 with other UCs and BSCs	156
Figure 88 Analysis of UC-4.3.....	158
Figure 89 Relationship of UC-4.3 with other UCs and BSCs	158
Figure 90 Analysis of UC-4.4.....	160
Figure 91 Relationship of UC-4.4 with other UCs and BSCs	160
Figure 92 Analysis of UC-4.5.....	162
Figure 93 Relationship of UC-4.5 with other UCs and BSCs	162
Figure 94 Analysis of UC-5.....	163
Figure 95 Analysis of UC-5.1.....	164
Figure 96 Relationship of UC-5.1 with other UCs and BSCs	165
Figure 97 Analysis of UC-5.2.....	167
Figure 98 Relationship of UC-5.2 with other UCs and BSCs	167
Figure 99 Analysis of UC-5.3.....	169
Figure 100 Relationship of UC-5.3 with other UCs and BSCs	169
Figure 101 Analysis of UC-5.4.....	170

Figure 102 Relationship of UC-5.3 with other UCs and BSCs	171
Figure 103 Analysis of UC-6.....	172
Figure 104 Analysis of UC-6.1	174
Figure 105 Relationship of UC-6.1 with other UCs and BSCs	174
Figure 106 Analysis of UC-6.2	176
Figure 107 Relationship of UC-6.2 with other UCs and BSCs	176
Figure 108 Analysis of UC-6.3	178
Figure 109 Relationship of UC-6.3 with other UCs and BSCs	178
Figure 110 Analysis of UC-6.4.....	180
Figure 111 Relationship of UC-6.4 with other UCs and BSCs	180
Figure 112 Connection of Application Scenarios with Operations, Architecture, Use Cases and Actors	181
Figure 113 Application Scenarios and Number of requirements	183
Figure 114 Application Scenarios and involved Actor Groups	186
Figure 115: A pool	214
Figure 116 A Pool with lanes	214
Figure 117 A Data object artifact	214
Figure 118 Petri Net modelling a simple process.....	215
Figure 119 State of the process immediately after “Submit offer” transition fired.	215
Figure 120 Basic Class Diagram notation	218
Figure 121 Basic notation of Sequence Diagram	219

LIST OF TABLES

Table 1 Modelling Standards comparison matrix	34
Table 2 UML tools comparison.....	35
Table 3 Representative list of personnel involved	38
Table 4 Categories identified (macro activities).....	39
Table 5 Categories of procedures based on the type of functions associated with	40
Table 6 Categories of procedures based on the type of “triggering”	41
Table 7 Comparator handling example of SOP at COMAU’s shop floor	45
Table 8 Antiturn Ring Check example of SOP at COMAU’s shop floor.....	46
Table 9 Template for Actors’ description	51
Table 10 COMAU Process Operator	55
Table 11 COMAU Technical Leader	56
Table 12 COMAU Design & Ergonomics Engineer	57
Table 13 SUNLIGHT Production Plant manager	59
Table 14 SUNLIGHT Production planner	59
Table 15 SUNLIGHT Production supervisor	60
Table 16 SUNLIGHT Foreman	61
Table 17 SUNLIGHT Worker	61
Table 18 SUNLIGHT Maintenance Manager.....	62
Table 19 SUNLIGHT Technician	63
Table 20 CERTH/CPERI Floor Manager	64
Table 21 CERTH/CPERI Process Supervisor	65
Table 22 CERTH/CPERI Maintenance Manager	65
Table 23 CERTH/CPERI Maintenance Supervisor	66
Table 24 CERTH/CPERI Process Technician	67
Table 25 CERTH/CPERI Control, Automation, IT Technician	67
Table 26 CERTH/CPERI Electrical Technician.....	68
Table 27 CERTH/CPERI Process Operator.....	69
Table 28 Connection between Application scenarios and groups of actors at SatisFactory	70
Table 29 Connection between Use Cases and groups of actors at SatisFactory.....	71
Table 30 List of Business Scenarios and Application Scenarios.....	73
Table 31 Template for Application Scenarios.....	75

Table 32 COMAU Application Scenario 1 characteristics	77
Table 33 COMAU Application Scenario 2 characteristics	80
Table 34 COMAU Application Scenario 3 characteristics	81
Table 35 SUNLIGHT Application Scenario 1 characteristics	90
Table 36 SUNLIGHT Application Scenario 2 characteristics	93
Table 37 SUNLIGHT Application Scenario 3 characteristics	95
Table 38 SUNLIGHT Application Scenario 4 characteristics	96
Table 39 CERTH Application Scenario 1 characteristics	101
Table 40 CERTH Application Scenario 2 characteristics	104
Table 41 CERTH Application Scenario 3 characteristics	108
Table 42 CERTH Application Scenario 4 characteristics	111
Table 43: Implementation of application scenarios.....	114
Table 44 Template for Use Cases - Mandatory fields.....	118
Table 45 UC-1.1 Process for handling shop floor related information	124
Table 46 UC-1.2 Storage of the shop floor information and data from the multi-sensorial networks	127
Table 47 UC-1.3 Analysis of real-time and historical info from the shop floor.....	129
Table 48 UC-2.1 In-factory training and support of workers using a flexible learning platform	133
Table 49 UC-2.2 Validation of training actions performed at the shop floor.....	135
Table 50 UC-2.3 Presentation of the shop floor procedures utilizing heterogeneous material.....	137
Table 51 UC-3.1 Online recognition of workers activities.....	141
Table 52 UC-3.2 Incident identification based on dynamically evolving operations	144
Table 53 UC-3.3 Monitoring and online notification of abnormal events or alarms	146
Table 54 UC-3.4 Identification of worker's and equipment's location	149
Table 55 UC-4.1 Provide maintenance work plans and actions related to human-centric activities .	152
Table 56 UC-4.2 Acquire work schedules and sequence of actions.....	154
Table 57 UC-4.3 Monitoring and decision support of operations and maintenance procedures	156
Table 58 UC-4.4 Provide workers availability and allocation of resources	159
Table 59 UC-5.1 Gamification framework.....	163
Table 60 UC-5.2 Platform for suggestions for improvement	165
Table 61 UC-5.3 Gamified Platform for suggestions for improvement.....	167
Table 62 UC-6.1 Provide informative analytics using advanced visual representation	172
Table 63 UC-6.2 Provide optimum actions and instructions with personalized dynamic information	175
Table 64 UC-6.3 Knowledge sharing among workers based on advanced reasoning.....	177

Table 65 UC-6.4 Presentation of shop floor information at the AR Glasses	179
Table 66 Categories of Requirements	182
Table 67 Connection of Application Scenarios with the group of requirements	183
Table 68 Relationship between Application Scenarios and Use Cases	185
Table 69 Use Case and SatisFactory Objectives	187
Table 70 End-Users Application Scenarios desired priority	188
Table 71: Response strategy categories at the SatisFactory shop floors	191
Table 72 COMAU BSC-1.1 Detailed Main Flow - Robot Wrist Assembly	194
Table 73 COMAU BSC-1.2 Detailed Main Flow - Welding Gun Body Assembly	194
Table 74 SUNLIGHT BSC-3.1 Detailed Main Flow –Preventive and corrective maintenance management system	195
Table 75 SUNLIGHT BSC- 4.1 Detailed Main Flow - Motive power battery assembly line.....	196
Table 76 SUNLIGHT BSC-4.2 Detailed Main Flow - Monitoring of the Cell Temperature during Jar formation and data collection.....	197
Table 77 SUNLIGHT BSC-4.3 Detailed Main Flow - Training platform for motive power batteries assembly line	197
Table 78 CERTH BSC-5.1 Detailed Main Flow - Replacement of a malfunctioning heating resistance	198
Table 79 CERTH BSC-5.2 Detailed Main Flow - Start-up procedures of VB01 Hydrocracking pilot plant	199
Table 80 CERTH BSC-5.3 Detailed Main Flow - Switching pilot plant operation from methane steam reforming to ethane oxidative dehydration.....	200
Table 81 CERTH BSC-6.1 Detailed Main Flow - Accident prevention of workers inside the shop floor area.....	201
Table 82 Alternative Detailed Main Flow - Accident prevention of workers inside the shop floor area	202

LIST OF DEFINITIONS & ABBREVIATIONS

Abbreviation	Definition
AUC	Alternative Use Case
AR	Augmented Reality
BPEL	Business Process Execution Language
BPM	Business Process Management
BPML	Business Process Management Language
BPMN	Business Process Modelling Notation
CIDEM	Common Information Data Exchange Model
EC	European Commission
EFFRA	European Factories of the Future Research Association
EU	European Union
GCRM	Gesture & Content Recognition Manager
HMI	Human Machine Interface
RFID	Radio Frequency Identification
SOP	Standard Operating Procedures
TEP	Training and Educational Platform
UC	Use Case
UML	Unified Modelling Language
VR	Virtual Reality
WO	Work Order
WP	Work Package
WSN	Wireless Sensor Network
YAWL	Yet Another Workflow Language

EXECUTIVE SUMMARY

The present document is a deliverable of the SatisFactory project, funded by the European Commission's Directorate-General for Research and Innovation (DG RTD), under its Horizon 2020 Research and innovation programme (H2020), reporting the results of the activities carried out by WP1. SatisFactory aims to develop an ecosystem of innovative technological components that would assist the daily operations of the people working at industrial environment. More specifically the developments of SatisFactory will be demonstrated to three diverse shop floors from discrete manufacturing (COMAU), batch products manufacturing (SUNLIGHT Systems) and continuous processes (CERTH/CPERI).

Deliverable D1.2 documents the overall context of the standards and tools that can be used to model the operations and procedures at the selected shop floors and includes a high level analysis of the procedures and their classification. Deliverable D1.2 is developed in an iterative approach and the present document is the third and final version (M27). The first version of the deliverable D1.2 was submitted on July 2015 (M7) and the second was submitted on March 2016 (M15). Since then, there has been a significant progress regarding the overall status of the project. Moreover, many new developments were applied regarding the procedures and the functionalities and this had a profound impact on the Application Scenarios, the Business Scenarios and the Use Cases, which are now finalized.

The main focus of the project is around the workers and how to improve their daily activities and increase the collaboration and engagement to the shop floor operations. A user centred approach through an iterative development process with participation of the relevant stakeholders is applied to continuously guide and also validate project developments at the shop floors. Thus, a thorough analysis of the involved actors and their responsibilities is also included.

Furthermore, deliverable D1.2 documents the activities that were performed for the analysis of the operations at these shop floors through a set of high level Business Scenarios with specific Application Scenarios that cover a wide range of actions involving a multitude of workers with different roles and responsibilities. At the beginning of each chapter, there is a brief description of the changes and the updates that have been made for this final version of the Deliverable D1.2 in order to easily locate the progress since March 2016. Finally, D1.2 includes a detailed analysis of the Use Cases that are developed to show the functionalities of the SatisFactory platform. These Use Cases have been used for the implementation of the selected Application Scenarios at the shop floors.

1 INTRODUCTION

The purpose of this deliverable is to provide a high-level analysis of the involved actors and their role in the project. Furthermore, there is an extended analysis of the high-level Application Scenarios and the Use Cases that fulfill the user requirements and needs. The purpose of the developments of D1.2 is to cover the operations and procedures that take place at the three selected industrial shop floors dealing with Automotive Machinery, Batteries and Chemical Processes according to the involved end users (COMAU, SUNLIGHT, CERTH).

1.1 PURPOSE, CONTEXT AND SCOPE OF THIS DELIVERABLE

The purpose of this deliverable is to give a systematic methodology of the set of use cases in conjunction with the identification of the involved actor groups that are necessary in order for the deployment of the SatisFactory platform in realistic Use Cases at each of the three shop floors. This document describes the activities to support user procedures analysis adapting it to the different environments involved in the SatisFactory project and provide a thorough analysis of the candidate use cases. These high-level procedures and the use cases will guide the development phases within the technical work packages, and therefore, this deliverable will be a common reference point for the SatisFactory consortium.

The identified actors, procedures and use cases in this deliverable reflect the work performed in Tasks T1.2 – “Models for actors and procedures interconnection” and T1.3 – “Use Cases and Scenarios”, with a close collaboration with the activities of Task “T1.1 - End-user and shop floor, system requirements and specifications” where the interview process conducted with representatives from the three application domains of the project and the list of initial requirements exploiting the “Volere” approach.

The **main objectives** of the activities that were performed by Tasks T1.2 and T1.3 are:

- Definition of the methodology for analysing the actual actors and procedures at the involved industrial shop-floor.
- Determination of Actor categories at each shop-floor (COMAU, SUNLIGHT, CERTH).
- Creation of the necessary models for the high-level analysis of the operating procedures.
- First step towards the creation of the vocabulary, which will constitute the hyper ontology of the Common Information Data Exchange Model - CIDEM (T1.4).
- Definition of a wide range of Application Scenarios, through which the innovative technologies and services of SatisFactory will be extensively evaluated.
- Definition of a wide range of Use Cases, through which the functionalities of the SatisFactory platform will provide a solid connection for the implementation of the Application Scenarios.
- Definition of Use Cases for different type of users (workers, managers, decision makers in shop floor, etc).
- Capture, analyse and communicate end-user needs for the proposed technology in an effective manner through the process of drafting the use cases.

- Determination of technological components and services to be used and evaluation of their usage at the shop-floor.

The developments of Deliverable D1.2 have been continuously updated and refined through an iterative process that led to the production of a total of three releases of this document, in Project Months M7, M15 and M27. The current document is the third and final version of the deliverable D1.2. The development of this deliverable was coordinated by SUNLIGHT with contribution of CERTH, COMAU, ABE, FIT, ISMB, REGOLA, EPFL and GLASSUP.

1.2 BACKGROUND

The background of the work performed and described in this deliverable is related to the first phase of the project “Definition” and aims at identifying a uniform approach for the description of the actions performed at the shop floors and the involved actors, combined with the potential technological components that could be applied and prototypes which will be built during the whole duration of the project.

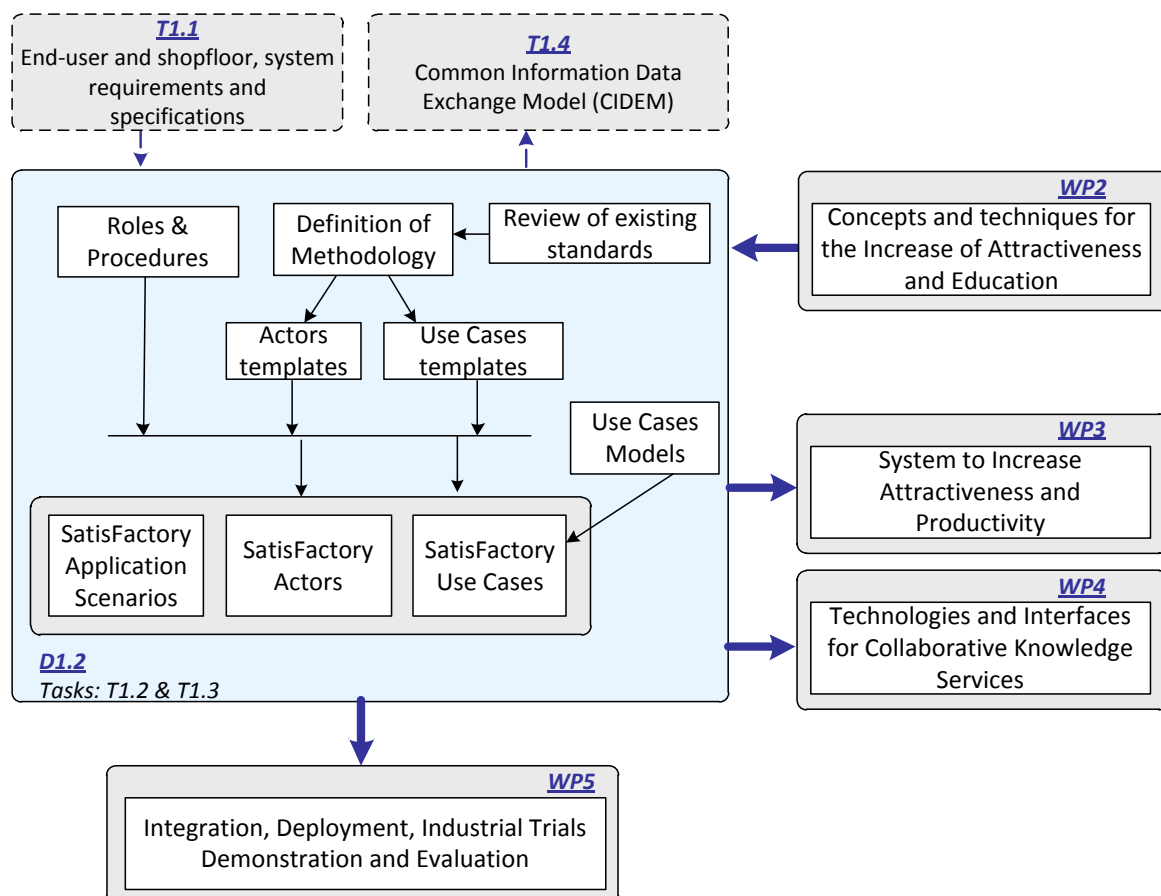


Figure 1 Activities and Connection of D1.2 with other tasks and WPs

More specifically, deliverable D1.2 results from activities of WP1 – “Domain Analysis and Requirements Engineering”, which is responsible for the definition of the requirements and

application environment for a safer and more attractive shop floor and the high-level procedures and recommendations for design and deployment of SatisFactory platform to end users shop floor. Within the Work Package 1, tasks T1.2 and T1.3 are focused on the development of user groups, namely the actors, and use cases according to the user needs and requirements (Task T1.1 – “User group definitions, end-user needs, requirement analysis and development guidelines”, documented at deliverable D1.1) of the project.

There exists a strong synergy among deliverable D1.2, derived by the activities of tasks T1.2 and T1.3, and other tasks in WP1 and other work packages within the project (WP2, WP3, WP4 and WP5). Furthermore, inputs from other tasks that run in parallel are required in order to develop a valid and solid methodology for capturing the Use Cases that will be applied during the project to demonstrate the functionalities of the SatisFactory platform and the benefits to the users at the involved shop floors.

This is the third and final version of the Business Scenarios and Use Cases. This version has been finalized in conjunction with the deployment of the SatisFactory platform, as it has been affected by the changes that have been made during the implementation at the shop floors (Task T5.3- “Deployment of Industry lab use case” and T5.4 - “T5.4: Industrial pilot demonstrators”). In many cases, the BSCs and the UCs have been modified from their initial description in order to be possible to be applied to the shop floors. A very important phase was the implementation at the pre-pilot shop floor, where many problems occurred and fixed, helping the SatisFactory platform to mature and to be applied to the other two shop floors more easily. The output from this deliverable created a structure and a methodology that connects the use case studies with the rest of the work of the project. Figure 1 shows the relationships between Tasks T1.2 and T1.3 and the other tasks in the project.

1.3 DOCUMENT STRUCTURE

Following this introductory section, the remaining part of the document is structured as follows:

- Chapter 2 provides a general overview of the existing standards for analysing the actual actors and procedures, the available execution standards, the modelling tools and a comparison of these tools.
- Chapter 3 describes an analysis of the role based procedures, including a description of their main classifications and the identified special needs and requirements.
- Chapter 4 include the results from the analysis of the shop floors and the definition of the involved actors and their tasks. In addition, a thorough analysis of the high-level procedures is included that will be further used for the documentation for the Use Cases of the project.
- Chapter 5 presents a high level description of the Business Scenarios and provides a detailed analysis for the involved Application Scenarios. The Application Scenarios illustrate where the SatisFactory platform have been deployed and used in a real environment.
- Chapter 6 presents a number of Use Cases that show how the architecture components fit into the shop floor environments. Also Chapter 6 describes the methodology for the development of Use Cases, the identified Use Cases that have been used for the implementation of the Application Scenarios at the shop floors and the respective high-level models.

- Chapter 7 assesses the application scenarios and Use Cases in terms of architecture component usage, feasibility of deployment, implementation effort, fulfilment of needs and requirements and connection with the project objectives. Chapter 7 also includes a prioritization of application scenarios importance for each shop floor. This chapter concludes with the description of the response strategies that are triggered during the implementation of the BSCs at the shop floors.
- Finally, Chapter 8 provides general conclusions and guidelines on how the results included in this deliverable will be further elaborated in forthcoming stages of the project activities, not only within the scope of WP1, but other WPs as well.

This document is supported by four annexes. Annex 1 contains the detailed main flow of the Application Scenarios. Annex 2 provides a list of the identified requirements as described in JIRA. This list is provided for completeness reasons since an analysis about the connection of the Use Cases and the requirements is performed at the analysis of each Use Case (Chapter 6). Annex 3 provides a brief description of the Architecture Components as defined by the actions of Task 2.1 and is documented at deliverable D2.1. Annex 4 contains the notation of modelling standards that can be used for Business Process Modelling.

2 REVIEW OF THE EXISTING STANDARDS FOR ANALYSING THE ACTUAL ACTORS AND PROCEDURES

The scope of Chapter 2 is to review the existing standards and tools in order to have a thorough understanding of the available methods for the analysis of the actors and the procedures that will be supported by the SatisFactory platform. Figure 2 shows the structure on this chapter. Starting from the Business Process Management (BPM), an analysis of Modelling Standards is addressed followed by the Execution Standards, the Modelling Tools and a comparison of the tools that have been used at this chapter. This analysis has been adopted as a reference for all the technical Deliverables of SatisFactory (e.g. D5.3). Following a specific set of Standards and using tools that are approved by International organisations made the implementation more efficient and less time consuming.

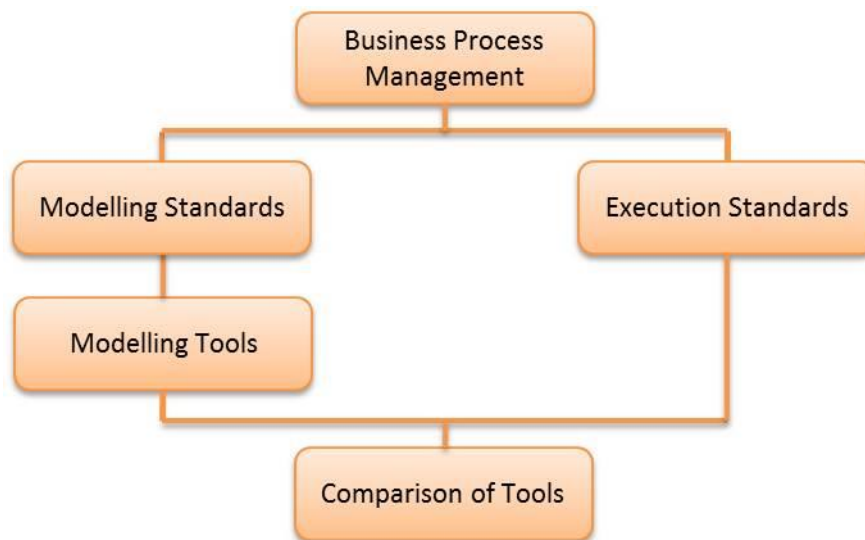


Figure 2 Content and Activities of Chapter 2

2.1 BUSINESS PROCESS MANAGEMENT / WORKFLOW MANAGEMENT

Task 1.2 (Models for actors and procedures interconnection) aims at creating the necessary models for the high-level analysis of the business processes of the industrial domains introduced by the SatisFactory project. Before creating these models, there is a need to identify and analyze the existing standards that can be used to carry out this activity, in order to maximize the efficiency and the impact of the produced models by selecting the most appropriate standard for the SatisFactory case.

Aligned to the above, the objective of the current document is to present the existing standards that can be used for analyzing the actors and procedures of the industrial factories. This review will start by providing definitions for some of the key concepts that will be used throughout

the document, present the full lifecycle of the Business Process Management activities and identify the subset of the BPM lifecycle that is of interest for the SatisFactory project.

2.1.1 Introduction

Since process is the key concept here we start by providing a definition of this term.

A **Process** is an approach to do something that consists of a number of activities, each of which will produce and/or consume some sort of artifact. Each of these activities is under the responsibility of a single stakeholder role.

In equivalence an **Artifact** is anything (document, product, etc.) that can be produced or consumed by a process or activity.

An **Activity** is the set of the behavioral steps involved in a process that produces and consumes artifacts and that is owned by stakeholders.

A **Stakeholder** is a *role* played by a person, place or thing that has some sort of interest in the outcome of the processes and activities. Stakeholders are not to be confused with people, since stakeholders are not persons in an organization but rather roles that a person can have. In many cases a person can be assigned with more than one role, while also a role can be associated with more than one person. As a result, a stakeholder is a role that a person, the environment, a place or a thing can have.

A **Business Process** is the configuration by which an organization (either Private or Public) carries out its activities across units or departments in order to produce value for its customers or stakeholders.

The Business Process Management (BPM) is defined as the procedure of supporting business processes using methods, techniques and software to design, enact, control and analyze operational processes involving humans, organizations, applications, documents and others sources of information. (van der Aalst, 2003)

The Workflow Management is defined as a subset of Business Process Management, with the lack of the diagnosis stage of the BPM lifecycle being the main difference between them.

2.1.2 BPM Lifecycle

Business Process Management is a multi-disciplinary subject, with many views, definitions and perspectives. In order to get a better understanding of the BPM terminology and nature it is preferable to start from a description of the full lifecycle of the Business Process Management activities. As shown in Figure 3, the whole lifecycle consists of four steps:

- Designing and simulating a business process (**Model and Simulate**). In this phase of the lifecycle business processes are electronically modelled. Graphical standards are dominant in this stage.
- Composing the existing Services (**Assemble**). This is a configuration phase, where the BPM System and the underlying infrastructure are configured. It is a stage that is hard to standardize due to the different IT architectures of different organizations.
- Mapping the assembly to a concrete infrastructure and using it (**Deploy and Execute**). The assemblies of services are associated with concrete implementations of them, which are eventually executed.

- Continuously improving the processes (**Monitor and Optimize**). In this phase Business analysts monitor the execution of the processes and identify problems as bottlenecks, or potential loops. This stage makes heavy use of diagnosis standards.

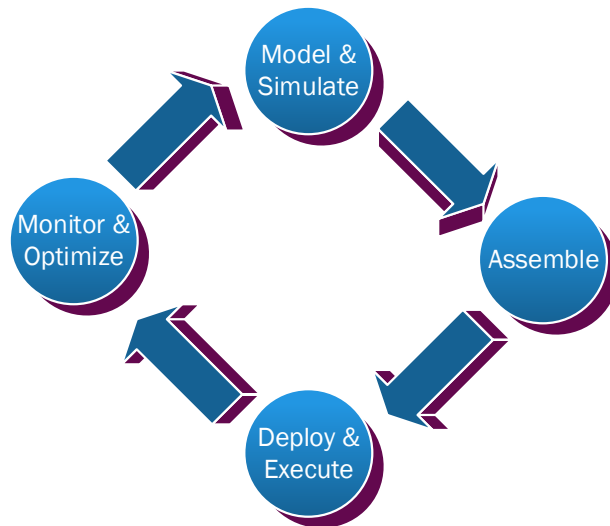


Figure 3 BPM Lifecycle

2.1.3 SatisFactory Scope

As already noted the activities related to Business Process Management in the context of SatisFactory project are mainly associated with the modelling and analysis of industrial Business Processes of the end users. Comparing this objective with BPM lifecycle that was presented in the previous section, we can say that SatisFactory can mainly focus on Modelling standards that can be used in order to capture procedures that will be initially introduced and later extended and optimized by the project activities.

2.2 MODELLING STANDARDS

A plethora of BPM standards, languages and notations have been developed and proposed throughout the years. Each of these standards addresses at least one of the various phases of the BPM lifecycle. In order to make sense out of the large number of standards, the most logical way is to categorize them into groups with similar functions and characteristics. The most obvious way to make this classification is to use the attributes of the lifecycle stage that these standards mainly belong to. Following this approach, standards are usually classified into the following three categories:

- Modelling standards
- Execution standards
- Interchange standards

As already referenced, the main focus of SatisFactory project is on modelling standards, so in the following paragraphs we will extensively describe a number of modelling standards (Business Process Modelling Notation, Yet Another Workflow Language, UML Activity Diagrams, Event-Driven Process Chains and Petri-Nets) and analyze them in terms of Strengths and Weaknesses, Standardization level, Background and Current Status. The detailed notation for each of the following standards can be found at “Annex 4 – Modeling Standards”

2.2.1 Business Process Modelling Notation (BPMN)

The Business Process Modelling Notation 2.0 (Object Management Group, 2011) is a notation used to graphically depict business processes. The language provides users the capability to capture their internal business procedures in graphical notation. In other words, BPMN is a graph – oriented visual language that allows to model business processes in a way that closely resembles a flowchart. This standardized graphical notation provides the ability to explain and exchange processes in a standards way and also to better understand collaborations and business transactions between organizations.

One of the main strengths of BPMN is that by using swim lanes, it allows for defining processes in different levels of granularity. For example the same process may be represented either at the company level or at the department level. On the other hand a major BPMN drawback is that there is no standardized XML format for interchanging BPMN diagrams. OMG has introduced the Business Process Definition Metamodel – BPDM specification but it is not yet supported by existing tools. Another weakness of BPMN is that it did not succeed in visualizing BPEL which was one of its initial objectives, making it very difficult and in some cases impossible to faithfully generate BPEL code from BPMN models.

2.2.2 Petri Nets

A classical Petri-Net is a directed bi-partite graph, which consists of two types of nodes referred to as **places** and **transitions**. Places are drawn as circles, while transitions are drawn as rectangles. Nodes can be interconnected with directed **arcs**, but connections between nodes of the same type are not allowed. A place *p* is called an input place of transition *t* if there is a directed arc *a* from place *p* to transition *t*. In the same manner a place *p* is called an output place of transition *t* if there is a directed arc *a* from transition *t* to place *p*.

Places may contain zero or more **tokens** which are drawn as black dots inside the circle. The state (sometimes referred to as **marking**) can be determined by the distribution of tokens over places. A transition *t* is said to be **enabled** if each input place of *t* contains at least one token. An enabled transition *t* may **fire**. In that case the transition consumes one token from each input place of *t* and produces one token for each output place of *t*. It is obvious that the firing of a transition *t* that is used to model a task or an action resembles the *execution* of that task or action. Upon the firing of a transition the Petri net can move from one state to another.

Petri Nets have mainly an academic rather than an industrial background and are very popular in theoretical approaches of process modelling. Although the notation is not standardized, they have been expanded with the addition of dependencies between tasks in the form of *pre-conditions* (conditions that must hold before the execution of a task) and *post-conditions* (condition that should hold after the execution of a task). The addition of conditions together with other enhancements to Petri Nets is called Workflow-net (WF-net).

2.2.3 Yet Another Workflow Language - YAWL

YAWL extends the class of WF-nets by adding multiple instance tasks, composite tasks, OR-joins and cancellation regions. In contrast to Petri-Nets and WF-nets, YAWL's visual representation allows tasks to be directly connected as a means of compressing the diagram. This direct connection can only happen for places that have only one input task and one output task.

YAWL is accompanied with a workflow editor and a workflow engine, which are open-source and released under the LGPL license, providing an integrated environment for creating and executing business processes. YAWL's main strength is the strong support for existing workflow standards (control flow, data and resource perspectives), together with comprehensive support for dynamic workflows in the case that a workflow needs to change after its deployment and for handling unexpected exceptions. On the other hand YAWL is an emerging BPM/Workflow system, which is not yet largely adopted by the end-users and lacks the integration with existing tools.

2.2.4 Unified Modelling Language - UML

UML is a language that aids the understanding of a model by representing it graphically. UML provides 13 different types of diagrams. Each type provides a different view of the system. Business Process Modelling mainly focuses on three specific types of diagrams, namely the Class diagram, the Activity diagram and the Sequence Diagram. UML (Version 2.0) was standardized in 2004 followed by some minor releases of the standard up to version 2.4.1 which is the last version formally released. UML is widely accepted as a modelling standard for capturing structure and behavior of a model and is considered as the backbone of the object-oriented software engineering computing paradigm that superseded the structural programming paradigm.

Some of the major strengths of UML and especially Activity Diagrams which are mainly used in Business Process Modelling are the following: (Marlon Dumas, 2001) (Russell, 2006)

- They support signal sending and receiving at the conceptual level.
- They support both waiting and processing states.
- They provide a seamless mechanism for decomposing an activity into sub-activities. The combination of this decomposition capability with signal sending yields a powerful approach to handling activity interruptions.

On the other hand, the weaknesses of UML AD are (Russell, 2006):

- Some of the UML constructs lacks a precise syntax and semantics. For instance, the "well-formedness" rules linking forks with joins are not fully defined, nor are the concepts of dynamic invocation and deferred events, among others.
- They do not fully capture important kinds of synchronization such as the discriminator and the N-out-of-M join. Similarly, they do not fully support the producer-consumer pattern with termination activity.

2.2.5 Event-Driven Process Chains - EPC

An **Event-driven Process Chain (EPC)** is a particular type of flow-chart that can be used for analyzing, modelling and potentially redesign the domain aspects of business processes. As with other standards, EPC is an ordered graph of events and functions. It uses an easy to understand notation and provides symbols to express the ability to execute processes in parallel, or the ability to

have alternate flows of execution. EPCs originate from the academic environment and although they were highly used in both academic and industrial environments they were never standardized. The method was originally developed as a part of a holistic modelling approach called the ARIS (Architecture of Integrated Information System) framework and since there are no new versions it is considered nowadays as a legacy method.

A major strength of EPC is claimed to be its simplicity and easy-to-understand notation. This makes EPC a widely acceptable technique to denote business processes. The known weaknesses of the standard are discrepancies which typically stem from the interpretation of (X)OR connectors and in particular the join case, unclear start, join/split balancing and the obligatory alternation of events and functions which is considered to be too restrictive because it makes it hard to identify the necessary events at the abstract level of the process description.

2.3 EXECUTION STANDARDS

As already described, modelling standards are used to create business process models in order to efficiently depict the overall operation of an organization. Execution standards provide to these organizations the ability to deploy the business process designs into a Business Process Management System (BPMS) and execute their instances by the BPMS engine. Each of the following standards are used for orchestrating the execution process and will be briefly described and analyzed since business process execution is not inside the SatisFactory project scope.

2.3.1 XLANG and WSFL

XLANG is a messaging language initially developed by Microsoft in 2001, which had as its design goals to use Internet standards as XML, XSD and WSDL while also supporting sending and receiving messages between .Net Framework based objects. XLANG is a messaging language with some of the expression capabilities of C#, without the portability features between XLANG and C#. XLANG is usually adopted to specify the details of the business processes, while the implementation details (e.g. database connection) are handled by a high level programming language as C#. XLANG is mainly used by Microsoft Biztalk Server and especially in Biztalk's Orchestration Designer where the end user creates orchestrations (combinations of business processes) by using a GUI and the system produces the appropriate XLANG output.

Web Services Flow Language (WSFL) is another XML based programming language, which was originally proposed by IBM in 2001 for describing Web Services compositions. WSFL was mainly composed of language elements that were used to describe business processes as collections of Web Services and a separate set of elements that were used to describe interactions between the description oriented elements. In 2002 Microsoft and IBM made a combination of XLANG and WSFL and created BPEL4WS, which was proposed to the Organization for the Advancement of Structured Information Standards (OASIS) and was finally accepted as a standard in the same year.

2.3.2 Business Process Execution Language – BPEL

BPEL is an XML-based language for specifying business processes in the web service environment and is currently the most influential execution standard in the market. Technically, BPEL can be seen as an XML-based programming language for Web Service compositions. The first version

of BPEL was called BPEL4WS and was originally submitted to OASIS WSBPEL Technical Committee by Microsoft and IBM in 2002. The second version of the standard was renamed to WS-BPEL and was approved as a standard by OASIS in 2007. According to BPEL each process in a Business Process Model provides an interface which is actually a Web Service that implements the functionality of the process, while it may also require some functionality which is also declared as an interface that is actually implemented by another Web Service. WS-BPEL is a language that allows orchestrating the above mentioned services, ranging from simply invoking them in a particular order and under particular conditions up to long-running state full conversations between services. The language also offers a recursive aggregation model that allows combining existing Web Services into higher level Web Services.

2.3.3 BPEL for People

As shown in the previous sections, the WS-BPEL standard introduces a language for describing automated business processes. However, in many practical situations, business processes require human interaction, meaning that automated service orchestration is not sufficient. BPEL4People takes advantage of the hooks that WS-BPEL offers in order to incorporate people as another type of participants in a business process.

BPEL4People introduces new concepts for processes like generic human roles. Each role defines the kind of interaction with the process. Examples of kinds of interactions with a business process can be process initiator, business administrator, etc.

Logical people groups are used in order to assign actual people to a human role. During deployment, each logical group can be associated with a set of users by retrieving actual users from an existing people directory (e.g. querying an LDAP service).

A third concept that is of actual interest is the concept of people activity. A people activity is a basic activity, which is used to integrate human actions within BPEL processes. The human task can be included within a people activity, referenced as a standalone artifact, or invoked as a separate service.

2.3.4 Business Process Management Language - BPML

The BPML is an XML process definition language that describes the structural representation of a process and the semantics of its execution (Havey, 2005). Business processes modelled in BPML run on an engine element by element, according to precisely defined semantics. Despite BPML being an XML-based code, it has a good balance of graphical and block-oriented paradigms. Therefore, the code of a BPML process has not only graph-oriented constructs such as loops and parallel paths, but also block-oriented constructs such as variables, recursive blocks and structured exception handlings. One of the key BPML design goals is that Business Processes can be executed in parallel with Web Service based BPMS's.

As previously mentioned, BPML is based on XML and so programmers do not have to make a deep dive on low-level programming language, but they only have to define processes and their execution sequences. Due to this fact, BPML is highly reusable, because its components can be easily parsed and reused in other business process definitions. In contrast with BPEL, BPML is formally complete and as such it can express complete end-to-end executable processes. Finally BPML

supports transactions, which is a way to enforce at least atomicity and consistency of execution of processes.

Due to the fact that BPML is a high level programming abstraction, it was not adopted by major vendors of BPM Systems, which in fact needed a simpler model and proved not to be ready to adopt BPML. For example Microsoft and IBM developed their own languages, namely XLANG and WSFL. These will be presented in the following section.

2.4 MODELLING TOOLS

In order to support the fast and efficient creation of Business Processes while also being aligned with the definitions of the above mentioned standards a number of tools can be adopted.

2.4.1 YAWL System

YAWL language is supported by an integrated system that consists of a Graphical User Interface (YAWL designer) which allows designing the specifications and the YAWL engine which stores these specifications in the YAWL repository (after performing all necessary verifications and task registration). The repository manages a collection of “runnable” workflow specifications.

The YAWL engine provides four interfaces:

- **Interface A** provides endpoints for process definition, administration and monitoring,
- **Interface B** provides endpoints for client and invoked applications and workflow interoperability and is used by services in order to connect to the engine, to start and cancel instances and to check work items in and out of the engine.
- **Interface E** provides access to archived data in the engine’s process logs
- **Interface X** allows the engine to notify custom services of certain events that may arise.

The YAWL Editor provides a GUI design environment for the specification and verification of YAWL workflows. It is an independent tool that interacts with the YAWL engine via Interface A. Figure 4 shows a screenshot of the control flow aspects of a YAWL model of a Credit Application Process in the editor.

The YAWL system supports only creation, management and running workflows using YAWL standard specifications.

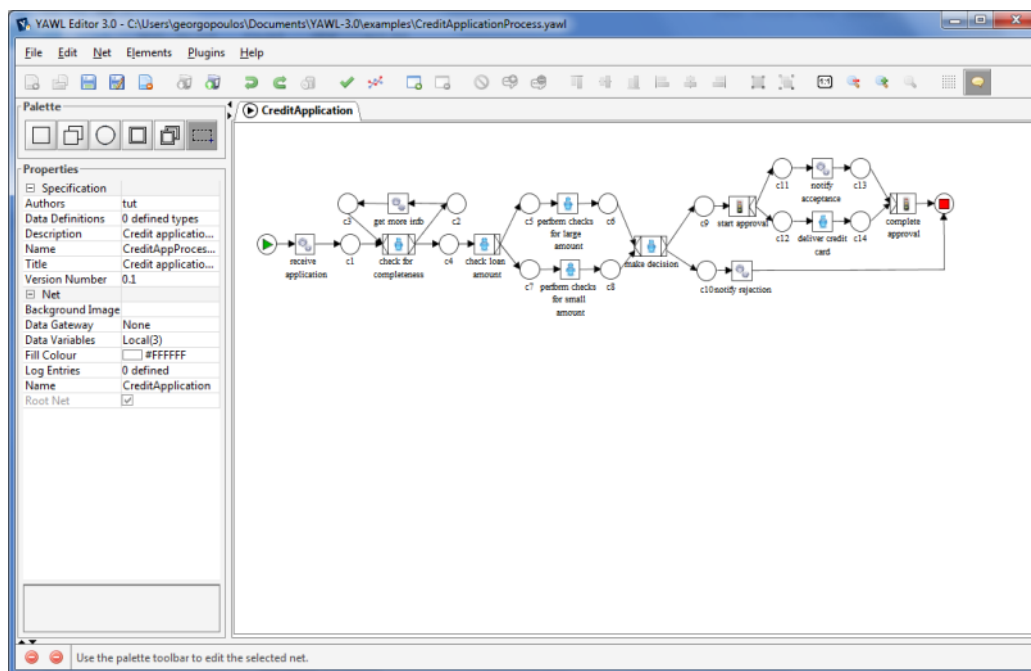


Figure 4 Control-flow specification in YAWL Editor

2.4.2 Modelio Open Project

Modelio is an open source modelling environment which can be extended through modules to add functionalities and services. The Modelio open source ecosystem consists of the following elements:

- The **Modelio core**, which is the main modeler with all the necessary components. It is licensed under the GPL license which requires that the destination software reusing the code should also be open source under GPL.
- The **Modelio Module Runtime** which is code that is embedded within Modelio modules. It manages module lifecycle and provides a rich Modelio-handling API. This code is distributed under the Apache Public License (APL) which provides a very large degree of freedom to anyone wishing to reuse and embed the code.
- **Modelio modules**. These modules are used to extend Modelio functionalities by providing characteristics as reverse engineering in order to automatically create code from a model, document generation and publishing, addition of new types of models, etc. Each module can be distributed under any license, commercial or open source, due to the openness of the APL license.

Existing modules of Modelio provide the ability to create Business Process Models in both **UML** and **BPMN** standards.

2.4.3 Intalio | bpmns Community Edition

Intalio|bpmns Community Edition provides a comprehensive platform that is used to design, deploy, and manage complex business processes by providing an intuitive visual designer and a

reliable high-performance process execution server. Intalio|bpms provides a central repository which is used to store the processes in order to ensure easy access and reusability when and where there is a need to do so.

Intalio|bpms supports a large number of W3C, OMG, and OASIS open standards which are relative to Business Process Management (BPMN, BPEL, SOAP, WSDL, JSON, JavaScript, Ajax, XML, XSLT, Xpath, Xquery, WS-Security) and this makes it ideal for Business Process Model creation, except the case that someone wants to use UML Activity Diagrams.

The basic modules of Intalio|bpms are the following:

- **Designer:** A graphical process modeler that uses BPMN version 2.0 notation in order to design Business Processes.
- **Server:** A scalable component that is used to run business processes and monitor their overall execution state.
- **Business Activity Monitoring:** A module that provides real time visibility and reporting with the use of Key Performance Indicators.
- **Business Rule Engine:** A module that is used to create, deploy and run simple or complex business rules, streamlining processes and efficiency.

According to the End User License Agreement of Intalio|bpms Community Edition, the use of the Intalio Software is permitted only by using Apache Tomcat and with a process data persistence provided by the Derby Java database or by the MySQL database. The authentication services should be the ones provided by the built-in file-based authentication or Apache DS.

Figure 5 shows a screenshot of Intalio|bpms Community Edition Designer, into which a process of buying a house has been modeled using BPMN.

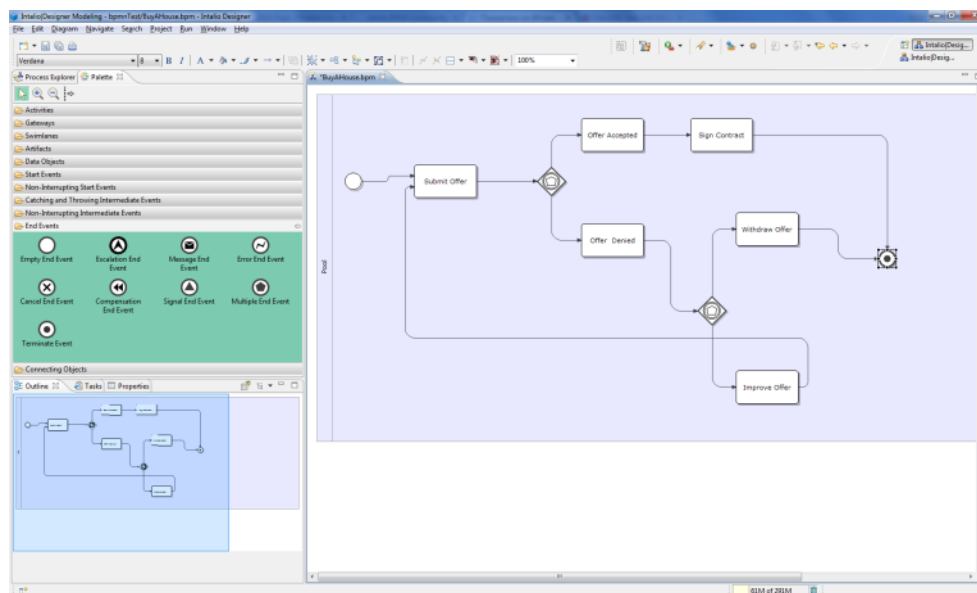


Figure 5 Intalio|bpms Designer screenshot

Intalio|bpms is based in Java technologies and the Designer is an extension of the well-known Eclipse Integrated Development Environment.

2.4.4 Visual Paradigm for UML Community Edition

Visual Paradigm Community Edition is a free (for non-commercial use) UML drawing tool that provides to the end users the ability to create the full set of UML diagrams by using an intuitive diagramming interface. Visual Paradigm Community Edition only supports UML out of the Business Process standards that have been presented in the current document, while Visual Paradigm Enterprise Edition (not free), also supports BPMN and EPC standards.

Visual Paradigm Community Edition also provides an extension mechanism that allows users to add their own functions to Visual Paradigm by developing plug-ins. By using the provided API, they can also query the model, such as read, create, update and delete diagrams and model elements.

One of the most interesting features of Visual Paradigm is that it can be integrated with all the major Integrated Development Environments (e.g. Eclipse, NetBeans, IntelliJ for Java and Microsoft Visual Studio for .Net Framework development), which means that developers can create or edit Business Process models directly from their preferred productivity tool.

Figure 6 presents a screenshot of Visual Paradigm for UML Community Edition, with a sequence diagram which represents the business process Schedule Inspection.

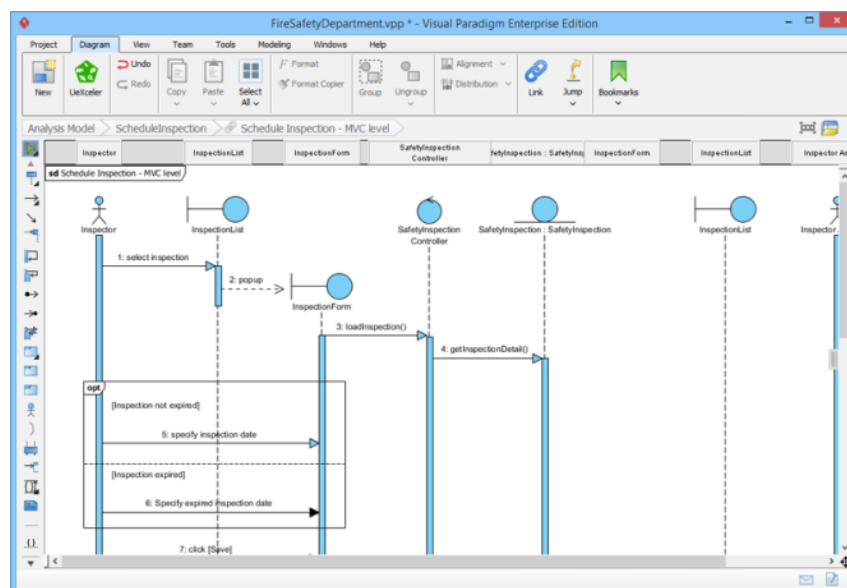


Figure 6 UML Sequence Diagram designed in Visual Paradigm

2.4.5 Microsoft Visio

Microsoft Visio is a diagramming and vector graphics application and is part of the Microsoft Office family. Visio provides a large number of templates, shapes and stencils that support a lot of formats and standards regarding modelling activities. Microsoft Visio supports all the business processes modelling standards that have been presented in Chapter 2, namely BPMN, Petri Nets, UML and EPC. Although some of the applications of Microsoft Office have been ported to MAC OS X platform, Microsoft Visio runs only on Windows platform. Additionally there is no free edition of the software. Visio, as referenced beforehand, is a part of Microsoft Office which is a very famous Office Automation suite of applications installed in a very large number of computers worldwide. On the

same time Visio can be adopted not only for modelling but also to perform a great number of other design tasks (e.g. Network design, Database applications, Mapping, Time Scheduling etc.), which makes it even more probable for an end user to be familiarized with the usage of the tool. Figure 7 shows a Petri Net business process designed with the use of Microsoft Visio 2013.

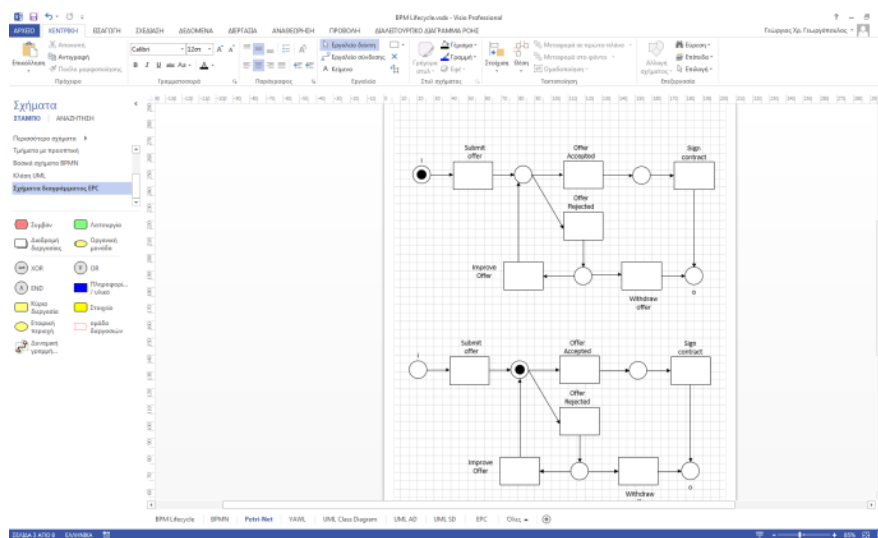


Figure 7 Microsoft Visio screenshot

2.5 COMPARISON OF STANDARDS AND TOOLS

Following is a matrix for comparison of the standards, which is used in order to summarize the information presented in Chapter 2.

	Background	Status	Standard?	Current Version	Strengths	Weaknesses
BPMN	Industrial	Stable	Yes	2.0	Different levels of granularity	<ul style="list-style-type: none"> - No XML format for interchange - Not all BPMN diagrams can be mapped to BPEL.
Petri Nets	Academic	Stable	No	N/A	Can represent current state of process	<ul style="list-style-type: none"> - Not standardized. - Other standards were based on Petri Nets and evolved them.
YAWL	Academic	Stable	No	3.0	Supports dynamic Workflows and Exception handling	<ul style="list-style-type: none"> - Not standardized. - Lack of support by any other tool except the built-in editor.
UML	Industry	Stable	Yes	2.4.1	- Integrated set of diagrams which provide	- No support for dynamic invocation and deferred

					different views of the Business Process (static and dynamic). - Widely used in Software Development Domain also. - Support for decomposing an activity into sub-activities	events. - Do not support synchronization as the N-out-of-M join.
EPC	Academic	Stable	No	N/A	Simple and easy to understand	- No clear semantics of some of the symbols. - Obligatory alternation between events and functions is too restrictive.

Table 1 Modelling Standards comparison matrix

Based on the above we consider UML approach to be the definitively preferable one for the modelling activities, due to the fact that it is a mature technology and language, it is widely used and accepted as a *de facto* standard in other domains and it is supported by many tools both free and commercial.

2.5.1 Comparison of Tools

Following is a matrix for comparison of the tools, which is used in order to summarize the information presented in Chapter 2.

Tool	Supported Standards	Current Version	Strengths	Weaknesses
YAWL Editor	YAWL	3.0	- Integrated to YAWL System - Open Source.	- Supports only YAWL
Modelio Open Project	BPMN, UML	3.3.1	- Modular architecture - Can be expanded with free or commercial modules	- Does not support execution and monitoring of processes. - Other standards were based on Petri Nets and evolved them.
Intalio bpms Community Edition	BPMN	7.0	- Supports executing and monitoring of processes	- Cannot be expanded. - Does not support UML.
Visual Paradigm for	UML, BPMN	12.0	- Supports integration with all major IDEs.	- BPMN is supported only in paid version.

UML Community Edition			- Provides API from diagrams management.	- Cannot export diagrams as images in community edition.
Microsoft Visio	BPMN, Petri Nets, UML, EPC	2013	- Part of Office suit, widely used - Supports a plethora of diagrams	- No free version. - Runs only on Windows.

Table 2 UML tools comparison

2.6 SELECTION OF MODELLING APPROACH FOR THE SATISFACTORY PROJECT

Based on the prior analysis of the existing modelling standards, we consider that the UML approach is the preferable one for the modelling activities, due to the fact that it is a mature technology and language, it is widely used and accepted as *de facto* standard in other domains and it is also supported by many tools both free and commercial. A high percentage of the project partners, especially those already involved in software development activities, are familiar with this standard, which added a lot of positive votes for its selection. Additionally UML provides both static and dynamic views of the Business Processes and supports decomposition of an activity to fine grained sub-activities, features that are very possible to be used in the SatisFactory case.

BPMN was also a highly rated candidate, but it was rejected due to the fact that there is no standardized XML format for interchanging BPMN diagrams and this could potentially bring problems in team cooperation. Petri Nets were not chosen due to the fact that they are not standardized, but they form the basis onto which other standards evolved. YAWL was also a good candidate because it provides an open source integrated editor tool which makes team work easier and more effective but the fact that it is not supported by any other major tool made a negative contribution to its selection. Finally EPC was considered an acceptable solution, mainly due to the simplicity of the standard, but the obligatory alternation between events and functions was considered to be too restrictive and eventually led to the rejection of the standard.

3 ROLE BASED PROCEDURES ANALYSIS

This chapter is intended to provide a technical and technological view in relation with a central aspect of the SatisFactory project i.e. the procedures that are applied to the shop-floor operations. In fact, they represent the fundamental element on which most of the results will be measured. The technical deliverables of the project (that can be described shortly as hardware and software, simple and/or complex solutions) include the analysis, optimization, description and the interactive presentation of selected procedures. Procedures can be related to training, production, maintenance, and to be performed by standard or planned conditions, or in emergency situations. The activities carried out in order to gather the information and analyze the procedures together with their connections with the special needs and requirements are shown in Figure 8.

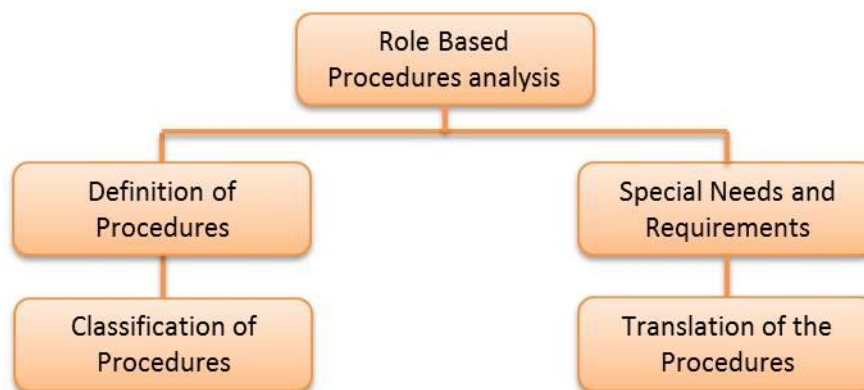


Figure 8 Content and Activities of Chapter 4

The methods described in this chapter have been applied to the SatisFactory project and played a significant role in the implementation of the needs and requirements of the project. The documented procedure definition methodology that resulted from this chapter is used to setup the Standard Operating Procedures which are described in details for each Business Scenario in Deliverable D5.3 which is related to task T5.3 – “Deployment of Industry lab use case”.

From a technical point of view, the management of procedures necessarily implies a good knowledge both of the context (e.g. Use Cases) and the methods to address the need to formalize the procedures themselves in such a way as to allow for an effective implementation of the innovative solutions of the project, based on context aware devices, AR devices and advanced HMIs. The role-based procedures can be classified and a clustering analysis will be performed to identify common actions or responses based on the requested incidents or nominally performed procedures. Special needs and requirements will be also defined.

This need to formalize procedures, introduces two specific topics included in this chapter:

- 1) The classification **of the procedures** themselves, in order to correctly route the identification of guidelines for the application development and to enable to identify the functional characteristics required for these applications;

2) The identification of **specific needs and specific requirements** related to the management of procedures.

Standard Operating Procedures (SOP) are steps for implementing various actions for:

- Manufacturing
- Maintenance
- Training

SOPs provide a direct interaction with the shop-floor actors at COMAU, SUNLIGHT and CETH targeting at the development of formalism for the involved sequence of steps involving:

- Implementation of a proprietary Software Development Platform for AR/VR
- Development of projects/prototypes at SatisFactory shop floors (COMAU, SUNLIGHT, CETH)

There are several examples of SOP at the shop floors of the SatisFactory End-Users.

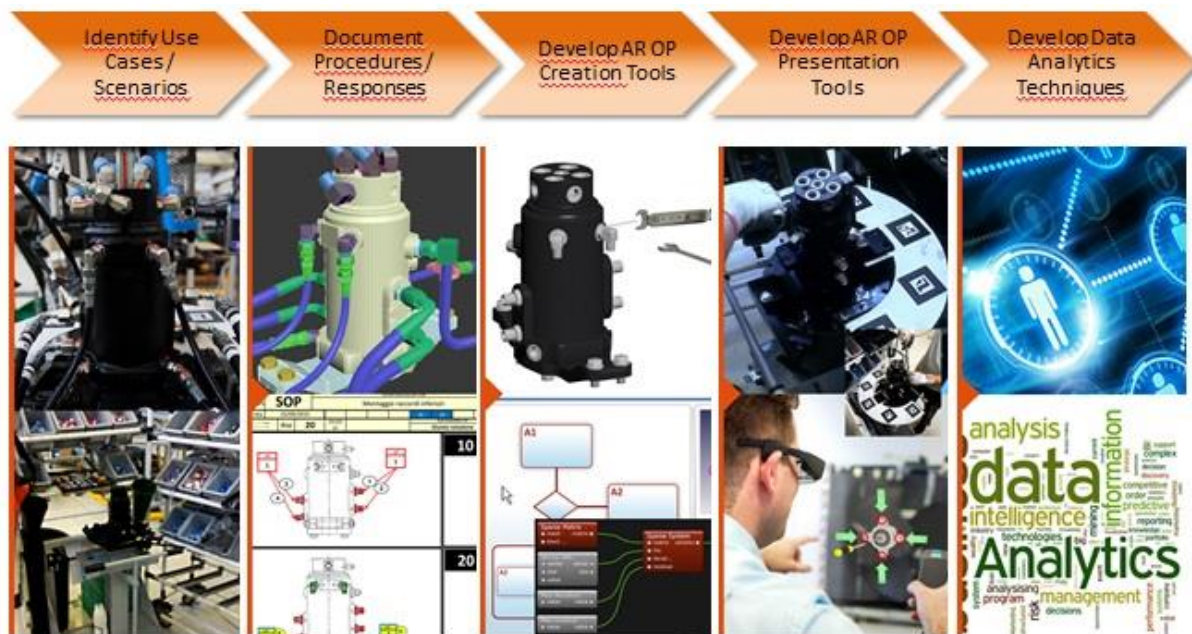


Figure 9 Standard Operation Procedure generic steps

3.1 CLASSIFICATION AND CLUSTERING OF PROCEDURES

The following paragraphs focus on the classification of the procedures, thus providing a practical methodology to identify and validate the use cases requested by the project. In particular, this classification focuses on the operating perimeters of the shop floor in order to circumscribe the scope of the tools. Among the matters to be taken into account in the next paragraphs we address:

- The type of processes the procedures belong to;
- The personnel involved in these procedures;
- The correct definition and classification of the procedures at the base of the selected use cases.

3.1.1 Type of process

The SatisFactory Project started with the user needs analysis, focusing on the areas of expertise of the end-user partners composing the Consortium. Such processes cover a wide range of European industrial sectors. They refer in particular to the Automotive Discrete Manufacturing, represented by the application in Automotive & Machining, where COMAU provides their expertise by the Batteries Manufacturing, leaded by Sunlight and, finally, the Chemical Process Industry, coordinated by CERTH/CPERI.

From a technical point of view, the development of effective and innovative solutions which can be inserted in the contexts indicated above and supporting the staff involved in the types of processes associated with them, actually represents a real challenge. This latter mainly derives from the heterogeneities of the involved procedures, by the high level of automation desired, from novelty from the attempt to "dress" the workers with devices and sensors to which they are not accustomed to and, especially, need to design and implement the most effective HMI possible, in order to welcome as they are realized in real work environment.

3.1.2 Involvement of personnel (actors)

One of the main objectives of SatisFactory is to improve the workplace linked in particular to the role of the Process Operator. However the analysis and the definition of the industrial context linked to the project and, in particular, the goal to identify the most representative use cases has made it immediately clear that it would have been necessary to widen the catchment area of roles involved to, at least, the top level of management (i.e. Foreman, Team Leader, Manager, etc...).

From a technical point of view, the analysis of the personnel involved at the level of the shop floor and the clear identification of the roles involved and the knowledge of the employees themselves is crucial to ensure that the design and the implementation of the HMI of different systems and tool developed, maximizes the effectiveness of the same. The user-centric approach in the definition of user interfaces, in the types of interaction with the devices and the introduction of the typical approaches of the gamification, not only is an explicit requirement of the project, but probably the only way to be able to effectively respect the spirit of SatisFactory.

The following is a representative list of personnel involved in the implementation of the procedures at the basis of the use selected cases.

Table 3 Representative list of personnel involved

ID	Actors
P1	Process Operator
P2	Process Manager/Supervisor
P3	Process Technicians
P4	Maintenance Team (manager/supervisor, technicians: electrical, process, control)
P5	Shop floor related actors (in general)
P6	Design Engineers

3.1.3 Classification of procedures

The SatisFactory project directly addresses a broad set of operational Use Cases, that will have to be covered in a timely manner from the documentation and the tools developed for the project selves, a demonstration of the effectiveness of new approaches and the use of cutting edge technologies.

From a technical point of view, an in-depth analysis of the requirements of the project, together with an accurate study of a lot of real operative procedures in real industrial Use Cases, has made it possible to identify multiple classifications of the involved procedures. The presence of multiple classifications is crucial to locate the set of technical and operational capabilities that the tools must implement and expose. Below the classifications are identified and a short description is provided.

3.1.4 Classification on the basis of the macro activities membership

This classification is a function of the type of macro activity for which the procedure itself was designed and described. In SatisFactory every primary activity may be described as a specific set of procedures. In the following table, categories are identified and described.

Table 4 Categories identified (macro activities)

ID	Category	Description
A1	Training	<p>They belong to this category all the procedures, sometimes coinciding with those directly carried out for the operational phases, created and/or selected for the training of new staff and the updating of staff already formed.</p> <p>As specific types of Training procedures that the project SatisFactory expressly requires there are:</p> <ul style="list-style-type: none"> • Assembly and Maintenance operating procedures • Critical issues on certain manufacturing operations • Best practices for daily/periodic operations in the shop floor • Predictive, condition based, Preventive and Corrective maintenance • Machinery monitoring, possible defects and workarounds
A2	Operational	<p>This category includes all procedures designed and described to provide accurate information relating to specific operational activities. Although the procedures found more frequently in this category include assembling and disassembling operations (Manufacturing), it actually includes all those procedures where it is evident that the operator must perform a precise sequence of actions, often linked to a specific check list.</p> <p>As specific types of procedures related to the operating environment that the draft SatisFactory expressly requests, are found:</p> <ul style="list-style-type: none"> • Majority of manufacturing operations • Assembly/Disassembly operating procedures

A3	Maintenance	<p>This category includes all procedures expressly designed and described to cope with activities of maintenance both daily, periodic and on emergency.</p> <p>As specific types of procedures of Maintenance that the project SatisFactory expressly requires it is possible to find:</p> <ul style="list-style-type: none"> • Best practices for daily/periodic operations in the shop floor • Corrective maintenance procedures (e.g. Replace a spare-part; loose a belt, etc...) • Most of Training/Manufacturing procedures already listed above
A4	Emergency	<p>This category includes all procedures expressly designed and described to deal with emergency situations. These procedures may in general involve not only the staff specifically trained to deal with the situation of an emergency solving the cause, but also the workers as a whole who, following specific directives or guided by an automatic system, are called to stand up in safety.</p> <p>As specific examples of emergency procedures that the project SatisFactory expressly requires are:</p> <ul style="list-style-type: none"> • Safe procedures on incident detection, by using an indoor localization system

3.1.5 Classification based on the type of functions associated with

This classification is a function of the type of technical/operational functionalities that the tools will implement to properly manage the description and the fruition of the procedures.

The main categories identified are:

Table 5 Categories of procedures based on the type of functions associated with

ID	Category	Description
B1	(Real-time) Notification System + Information system	The procedures belonging to this category refer to the procedures which must be carried out to face a notification of a particular event (both common and on alarm). The system allows providing specific information on the event and all the associated relevant information, describing the procedure to be followed, in order to better manage the event by the employee.
B2	System to support the execution of a procedure	The procedures belonging to this category are all that provide step-by-step information related to a given task. Although many of these procedures are directly associated with activities of assembly/disassembly, in this category all the procedures that can be described by a precise sequence of actions are included.
B3	System for remote collaboration	This category includes all the procedures expressly designed to effectively remotely support a worker on the shop floor by an operator/remote expert. Although many of these procedures are usually associated to maintenance by distance, in the scope of the project these procedures can be designed to help workers directly on their workplace in case of difficulty, and be consumed by the

		latter on the basis of indications of other more experienced workers.
--	--	---

3.1.6 Classification based on the type of "triggering"

This classification is a function of the type of activation that leads to the tools, made available to workers, to select, load and visualize a specific procedure.

From a technical point of view, this classification is essential to correctly identify the types of interfaces/connections between the different components of the underlying architecture of the project. The tools made available to the workers should be able to communicate effectively with components of the remote system and, through these, with the network of sensors and physical devices present in the shop floor level. This is the only way it is possible to ensure a strong performance in notification of happened events (either scheduled or on emergency) and the subsequent execution of the procedures associated with them. The main categories of procedures identified according to this classification are described in the following table.

Table 6 Categories of procedures based on the type of "triggering"

ID	Category	Description
C1	On Demand	All the procedures voluntarily activated by the worker through the tools at his disposal. The request may occur either manually by selecting a specific procedure or by using a system of recognition (e.g. a webcam and a marker) which allows the automatic selection, loading and visualization of a specific procedure linked to the current context
C2	On Event (asynchronous)	All the procedures that are activated automatically by the system as a consequence of a particular event asynchronously happened during the activities conducted by the worker (e.g. notification of an alarm linked to the system of incidents detection based on tracking the position of workers within the shop floor). In this case, the worker will receive a specific notification linked to the event together with the procedure to follow. Almost the totality of the triggering events is linked to situations of criticality and emergency.
C3	On Planning	All the procedures that are triggered based on a predetermined scheduling/planning e.g. the periodic maintenance, the daily control and/or to specific hours, etc...

3.2 SPECIAL NEEDS AND REQUIREMENTS

The following paragraphs have the objective to focus on specific technical needs that it is necessary to identify and cover in order to satisfy the project requirements. They are:

- The procedures associated with the selected use cases must be **translatable** so that they can be correctly handled by tools that will be implemented to support the activities of the involved workers (for example by the Augmented Reality Tools);

- The contents identifying the body of procedures should be **presentable** through the use of tools directly provided to the involved workers, compatibly with the possibilities offered by physical devices on which the software will be performed (e.g. AR Glasses). With the term "content" is meant here both the type of formalism chosen to describe a procedure and the type of "resources" used to be presented/displayed (e.g. images, video, 3D models animated, audio clips, etc.);
- The implemented procedures should be activated and (when dealing with a simple selection of users) automatically identified by the system (e.g. emergency situation automatically found, with a consequent notification to workers of procedure to be followed to cope with the emergency itself).

The following paragraphs will provide details of each of these needs arriving to define precise technical requirements.

3.2.1 Translation of the Procedures

One of the principal needs concerning the administration of procedures is represented by having to translate/convert the original procedures into a format manageable by tools made available to workers at the shop floor level. The complexity of this procedure depends on many factors. Among those, we highlight:

- **Formalism used to describe the original procedures.** The analysis of numerous Operating Procedures (OPs) from different industrial contexts (large companies), showed how the OPs are described in various ways and with a level of detail that is not uniform. As an example we cite here: (A) OP described in slideshow documents using textual parts for the explanations and many real images/photos to clarify the indicated operations; (B) OP described in spreadsheets with an *ad hoc* layout where each action is described in a formal way respecting descriptive slot such as the instruments to be used, the part-number of the component to be mounted, 2D/ 3D views of the CAD model representing the real object, textual description of the action to be performed, symbology relating to safety standards to adopt, etc...; (C) OP written in a more descriptive format, similar to a user's manual, saved in electronic formats.
- **Facility in finding the resources used to describe the original procedures.** Among the most important resources we cite 2D/3D CAD models, digital images, photos, videos, further documentary material.
- **Case studies – Types of procedures to manage.** SatisFactory requires the selection of use cases relating not only to different scopes (Training, Manufacturing, Operation, Maintenance), but also to the application of the developed tools to different Use Cases, in which the procedures themselves should cover both Standard Operating Procedures (SOP) and Emergency Operating Procedures (EOP). Such a variety of procedures necessarily impacts on aspects of modeling, and implementation that must take in account of the wide context to manage;

- **Case studies – Interfaces/tools used in the execution of a specific procedure.** The analysis of the specific analyzed procedures and the context in which they are currently performed highlights how even within the same scope (e.g. manufacturing), workers act using different tools and interfaces. Significant example of this heterogeneity are SCADA interfaces, assembly tools (e.g. torque wrenches, screwdrivers, etc...), common industrial PC interfaces usable with trackball and touch screen, etc...

-

3.2.2 Specific requirements related to the translation of the original procedures

Given the above mentioned discussion, it is possible to derive two crucial technical requirements related to the translation of the description of original procedures into a format which should be manageable by tools made available to workers. These requirements are:

- 1) Identify and/or design a set of “guidelines” in order to collect in a homogeneous and well organized way all the information related to the operational procedures that are part of the selected use cases.
- 2) Select and/or design formalism in order to “re-describe” the original procedures so that they can be handled efficiently by software tools adopted by the workers at the level of shop floor.

3.2.3 Requirements of "guidelines" to be used in collecting relevant data

The guidelines should drive in the collection of all the information necessary to the translation of the original procedures. They must include (at least) the following actions:

- 1) Identification and/or selection of operational procedures to translate;
- 2) Identification of persons who have contributed to the definition of the procedures and/or having a sufficient capacity to explain them in detail;
- 3) Obtaining the documents describing the currently operating and emergency procedures;
- 4) Analysis of the documents obtained for the identification of all the resources shown and/or referenced from the procedures (e.g. digital images, photographs, 2D/ 3D models, CAD drawings, videos, other documentary material, etc.);
- 5) Selection of resources that will be able to contribute to the translation of the original procedures and which will become part of the contents displayed directly by software tools provided the workers of the shop floor;
- 6) Obtaining all selected resources (e.g. 3D models) in supported formats;
- 7) Any work of conversion and/or re-editing of resources do not comply with standards/formats supported.

The guidelines need to be formalized in a specific document and used as a sort of check-list in order to guide the initial phase of management of operational procedures selected.

3.2.4 Requirements of "formalism" to be used for the translation of original procedures

The formalism required for the translation of the original procedures, must be selected and/or designed to satisfy the following macro requirements:

1. Allow to describe the most common forms in which the procedures are generally structured (e.g. Procedure- >Operations- >Steps- >Actions);
2. Allow a description extremely flexible of actions under the procedures, which must cover in a comprehensive manner, the wide range of actions commonly found in the procedures, manage conditional constructs, manage any preconditions, include references to specific resources (e.g. animation of a 3D model), etc...
3. Allow to efficiently address the usually expensive stage of content creation (e.g. 3D animation, management of a lot of different file formats, etc...), which may mark the failure of the task or bring high costs not initially accounted for;
4. Simplify the description of procedures (or parts of them) to reach the objective point of making these processes fully automated or at least "extremely" guided;
5. (Highly desirable) Permit an approach "single-description / multi-presentation", that is the ability to describe the same procedure by a single description based on multiple information levels and to be able to present this single description on different devices and software, filtering and using only the supported content.
6. Allow an effective and efficient software implementation of the formalism itself;
7. Ensure management of the elements which constitute the formalism, through a high-level user interface, in large part of visual type;
8. Maximize the efficiency of the processing at runtime of derivate tools, so as to meet the final requirements for the creation of "real time applications" (especially in the aspects that most have to do with the 3D models visualization and with the interaction with the external environment).

3.2.5 Presentation of the Procedures

Although the translatability of the procedures is the basis for any further adoption of these techniques, it is necessary to highlight some specific needs specifically related to the utilization of "translated" procedures:

- The description of the procedures translated must be based on a content actually manageable by tools of presentation (e.g. Visual Analytics Modules, Advanced HMIs, Augmented Reality tools);
- The content describing the procedures must be viewable by the physical devices on which the tools of presentation will be executed (e.g. primarily the GlassUp AR Devices). From this point of view this means that the type of content is closely dependent on the technical characteristics of a particular device: computing power, 3D display support, display resolution, etc...

3.2.6 Requirements related to the environment

In parallel with the needs and requirements directly related to operating procedures of the selected use cases, it should be emphasized that the ability to manage them by the tools depends on a large set of environmental factors. Some of these factors can be highly blockers while others can simply worsen the performance of the system.

Among the environmental factors with the highest impact on the support offered for the implementation of operational procedures, we can find:

- Lighting
- Materials of surfaces
- Visibility of the components
- Level/quality of the connection/networking
- Possibility of positioning marker/references in the environment
- Possibility of introducing new tag on instruments and/or components

3.2.7 Example of a Standard Operation Procedure

At the shop floor there is a wide range of procedures that are performed daily by the workers. For those that follow predetermined steps for their completion, a SOP exists that guide the workers. Two indicative examples are included in this section to show what a subset of actions may contain. Both examples are taken from the COMAU shop floor.

3.2.7.1 Comparator handling example

The first example of a Standard Operation Procedure is extracted from COMAU Application Scenario 1 (see Chapter 5) and explains the handle of a Comparator during a specific task at COMAU shop floor. The following table presents this procedure.


Table 7 Comparator handling example of SOP at COMAU's shop floor

<p>a) Don't clear the Comparator</p> <p>b) Place Dynamometer over the bar</p> <p>c) Pull in upwards up to a force of 24 kg</p> <p>d) View comparator for share collapse</p> <p>e) Release the lever</p> <p>f) Display the comparator and take backlash quota</p>	
--	--

3.2.7.2 Antiturn Ring Check example

The second SOP example comes again of COMAU's Use Case 1. It explains the procedure of fixing a faulty item (antiturn rotation ring) which is part of a complicate machine at COMAI's shop floor. This procedure includes a condition based decision according to a verification result during this fixing.

Table 8 Antiturn Ring Check example of SOP at COMAU's shop floor

<p>Execute:</p> <p>Fix the antiturn rotation ring:</p> <p>a) Lock with hands the gear to the body with 3 screws</p> <p>b) Check by hand the antiturn ring</p>	
<p>Verification</p>	
<p>NOT OK:</p> <p>Remove the Gear and check out:</p> <ul style="list-style-type: none"> • The positioning of the antiturn Ring • The seal mounted on the body b) Check by hand the antiturn ring 	<p>OK:</p> <ul style="list-style-type: none"> • Complete locking gear with appropriate screws • Close as needed in torque

4 ACTORS AND PROCEDURES

The goal of Chapter 4 is the definition of the modelling methodology, taking into account existing standards (e.g. Business Process Modelling tool) for analysing the actual actors and procedures of the industrial shop floors (COMAU, SUNLIGHT and CERTH). Following detailed interviews with the end-users (as documented at D1.1 – “D1.1 User group definitions, end-user needs, requirement analysis and deployment guidelines”), this task will lead to the creation of the necessary models for the high-level analysis of the business processes of the industrial domains introduced by SatisFactory. In this chapter, there is a detailed analysis of the Actors of each End-User and the methodology that has been used. The Actors’ groups have been created and described with details based on the needs and procedures on each shop floor. The Actors will be connected with the Use Cases and Application Scenarios at a later chapter.

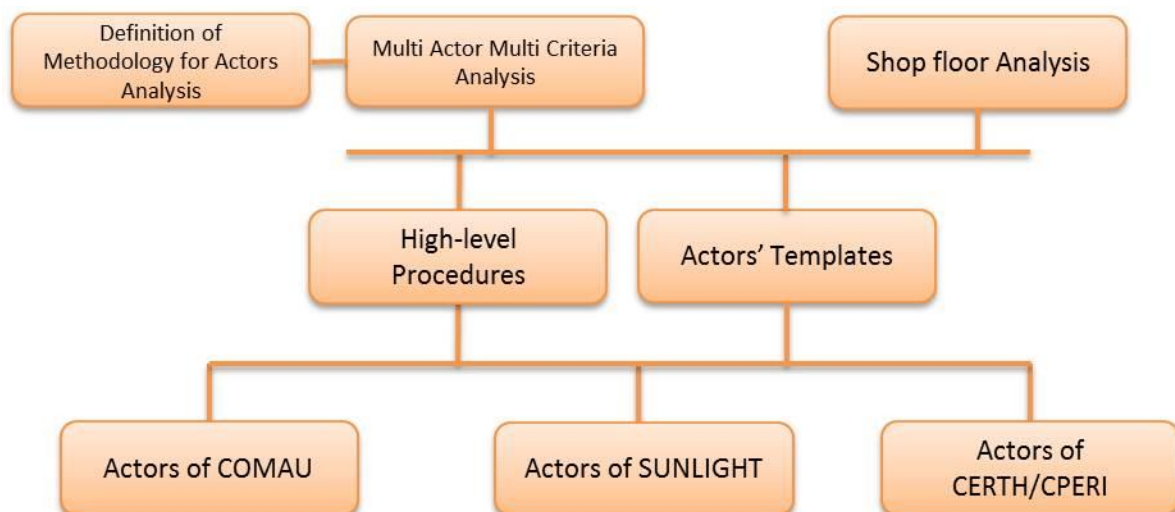


Figure 10 Content and Activities of Chapter 3

Chapter 4 gives input to the activities of Task T1.3 related to i) *Type of process*, ii) *Involvement of personnel* – Workers involvement in the tasks and related personnel at the shop floor level and iii) *Working task to be addressed* – Definition of the type of maintenance/assembly/disassembly task that should be addressed by the SatisFactory architecture. The output of the system will be the suggested actions, implemented through the aforementioned means of interaction with the equipment or the devices, fully integrated into the middleware as foreseen at the activities of Task T4.4. At the second iteration of the Deliverable D1.2 section 4.4.4 was created which describes the correlation of the groups of actors with the Business Scenarios and the Use Cases.

4.1 DEFINITION OF METHODOLOGY FOR ACTORS ANALYSIS

At the start of a new project an important initial step is to identify the stakeholders and their needs and interests. Stakeholders can be individuals, groups and organisations who may directly or indirectly influence or be influenced by the project, both in terms of the development process and the project outcomes. Though three application domains, Automotive Machinery, Batteries and Chemical Processes, have been selected as initial focus, the potential of the project outcomes is much wider, and therefore the involved actors cover a quite diverse group of workers and stakeholders. Therefore, the list of identified actors in this analysis is not comprehensive, but it represents some of the obvious candidates with particular emphasis on the selected domains.

More specifically, during SatisFactory project, the term “Actors” identify all specific roles involved in the manufacturing process, while all supporting design and engineering roles, as well as connected staff functions are named “Stakeholders”. More precisely the Project will focus and develop applications for the “Actors”.

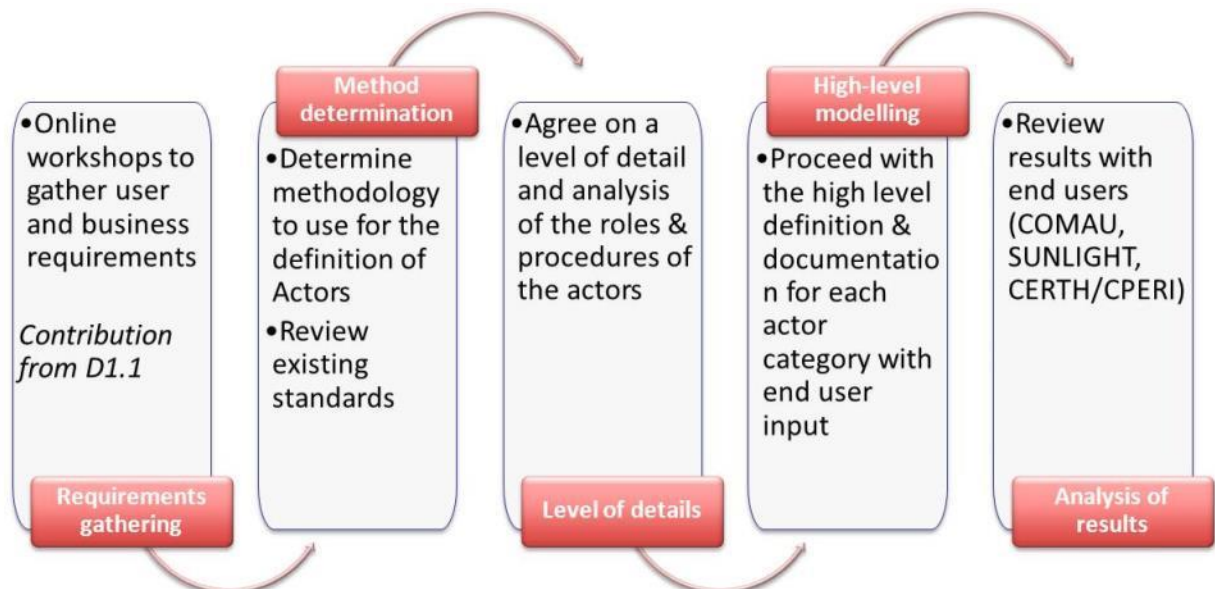


Figure 11 Definition of the modelling methodology for analysing the actual actors and procedures of the shop floor

Figure 11 depicts the stages that were applied in order to gather the appropriate information for the analysis of the actors and the procedures. Overall this sequence of activities was performed in parallel with the activities of Chapter 3, where the procedures and their classification are documented.

4.2 MULTI ACTOR MULTI CRITERIA ANALYSIS

A Multi Actor Multi Criteria Analysis (MAMCA) approach has been modified and applied for the definition and description of the actors to be involved in the SatisFactory Use Cases. These actors interact with each other, with the components and the systems involved for the realisation of

procedures. The MAMCA allows evaluating different involvement of the different stakeholders that coexist at each shop floor. The methodology consists of 5 steps as shown at Figure 12.

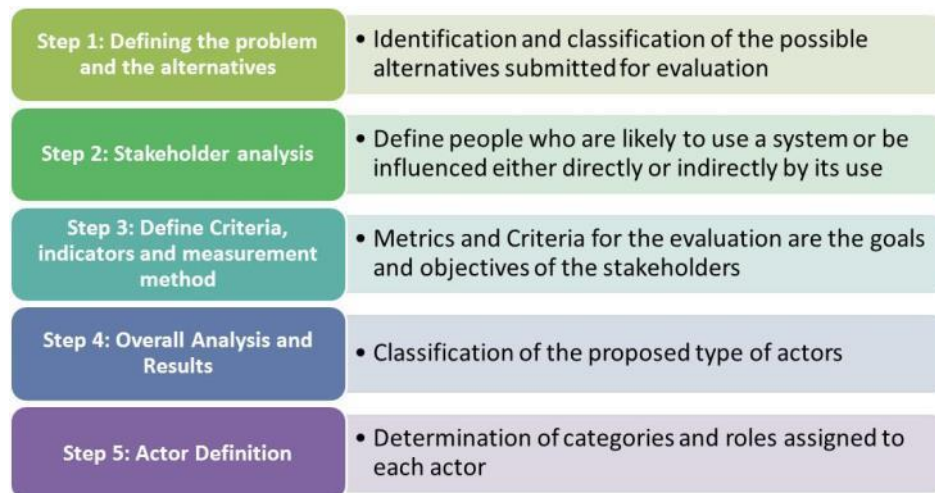


Figure 12 Steps to define the actors at the shop floors

The approach that was used is:

- The first step is the definition of the problem and the identification of the alternatives. These alternatives can take different forms according to the problem situation. For SatisFactory project the problem is related to the fulfilment of the objectives as described at DoW.
- The second step involves the analysis of the stakeholders. A stakeholder can be defined as the range of people who are likely to use a system or be influenced either directly or indirectly by its use. In other words, stakeholders are people who have an interest, financial or otherwise, in the consequences of any decisions taken. An in-depth understanding of each stakeholder group's objectives is critical in order to appropriately assess the different alternatives. Stakeholder analysis should be viewed as an aid to properly identify the range of stakeholders which needs to be consulted and whose views should be taken into account in the evaluation process.
- The third step involves the selection and definition of evaluation criteria which are primarily based on the identified project objectives and stakeholders' roles and connection to the project's developments. Generally, for each stakeholder group, we first track a preliminary criteria list based on the interviews and shop floor analysis. Next, during interactive discussions with stakeholders (e.g., by teleconference, workshops, etc.), each stakeholder group gets the opportunity to evaluate and validate the outcome of the interview findings.
- The fourth step evaluates the group of actors on the different shop floors based on their responsibilities. For this purpose information from the interviews are used. A common questionnaire for tasks T1.1 and T1.2 was used in order to gather information for the role of the involved personnel. The results from this process are described in detail at deliverable D1.1 "User group definitions, end-user needs and requirement analysis and development guidelines".
- Finally the fifth step determines the selected categories and the roles of each group of actors at each shop floor.

4.2.1 SatisFactory Main Categories of Actors

The implementation of the aforementioned approach relied on a template that was developed having in mind the diversity of the actors at the involved shop floors. Their tasks and roles are specifically defined. Also the interviews provided the initial information about the group of actors. Overall the main categories for the actors are show based on their role. There are three main categories identified which are common for the three shop floors:

- Managers and Engineers
- Supervisors
- Operators and Technicians

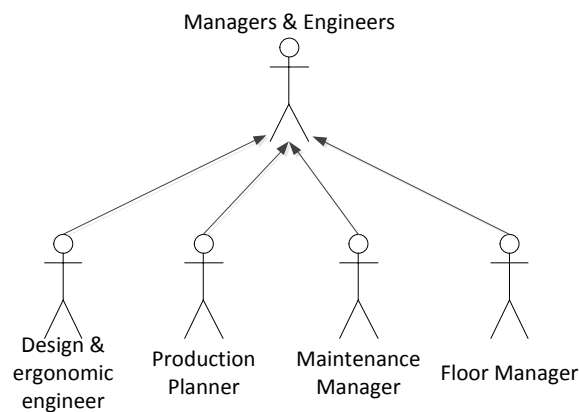


Figure 13 Actor Category – Managers and Engineers

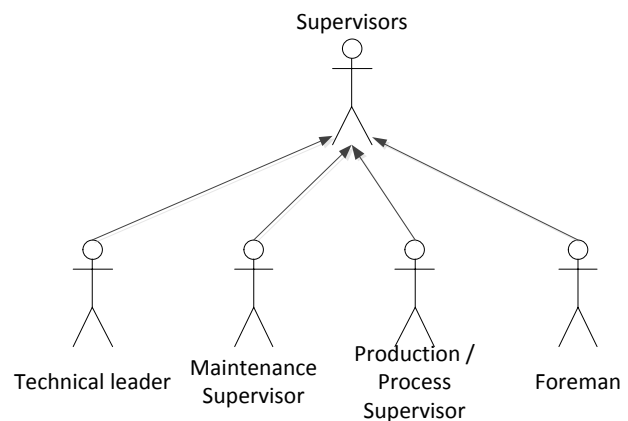


Figure 14 Actor Category – Supervisors

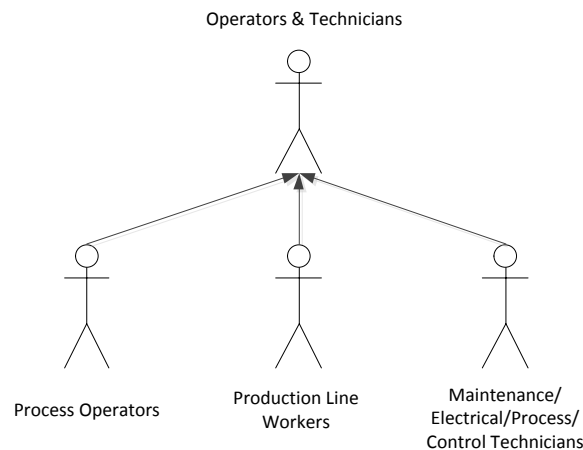


Figure 15 Actor Category – Operators and Technicians

For each of these categories the groups as defined at the shop floors are identified. These categories summarize the hierarchy which is present at the shop floors and defines the interaction of the employees with the Application Scenarios (Chapter 5) and the defined Use Cases (Chapter 6). The identified actors are those that will directly interact with the SatisFactory system.

4.2.2 Template for definition of Actors

At Table 9 the template fields that was used for the description of the involved actors is analysed.

Table 9 Template for Actors' description

Group Name	<i>Enter the name of the actor's group</i>
Category	<i>User or Stakeholder</i>
Demographical Data	<i>Specify gender or age area (if needed)</i>
Tasks	<i>Specify the tasks that are performed by the actors</i>
Expertize	<i>Enter if any experience-expertize (and what kind) is required</i>
Social Environment	<i>Specify potential groups for collaboration</i>
Physical Environment	<i>Specify the working area of the actor</i>
Experience Level (optional)	<i>Trainee, Novice or Experienced</i>
Aspects / Workflows (optional)	<i>Specify any common activities and sequence of procedures performed daily</i>

This template was circulated to the end users (COMAU, SUNLIGHT, CERTH) in order to have a detailed description of the involved actors and their activities. The results of this information gathering procedure is analysed in a subsequent section of this Chapter.

4.3 HIGH LEVEL PROCEDURE DESCRIPTION

It is imperative to formalise the description of the procedures to be implemented, in order to have a unified approach, to keep track of all the steps to be taken, to avoid gaps, to better understand them and to keep record of them. The approach for the high level procedure description will be based on *Dr. Cockburn's* approach on 'Writing Effective Use Cases' and on *BS EN 13460:2002 Maintenance – Documents for maintenance*.

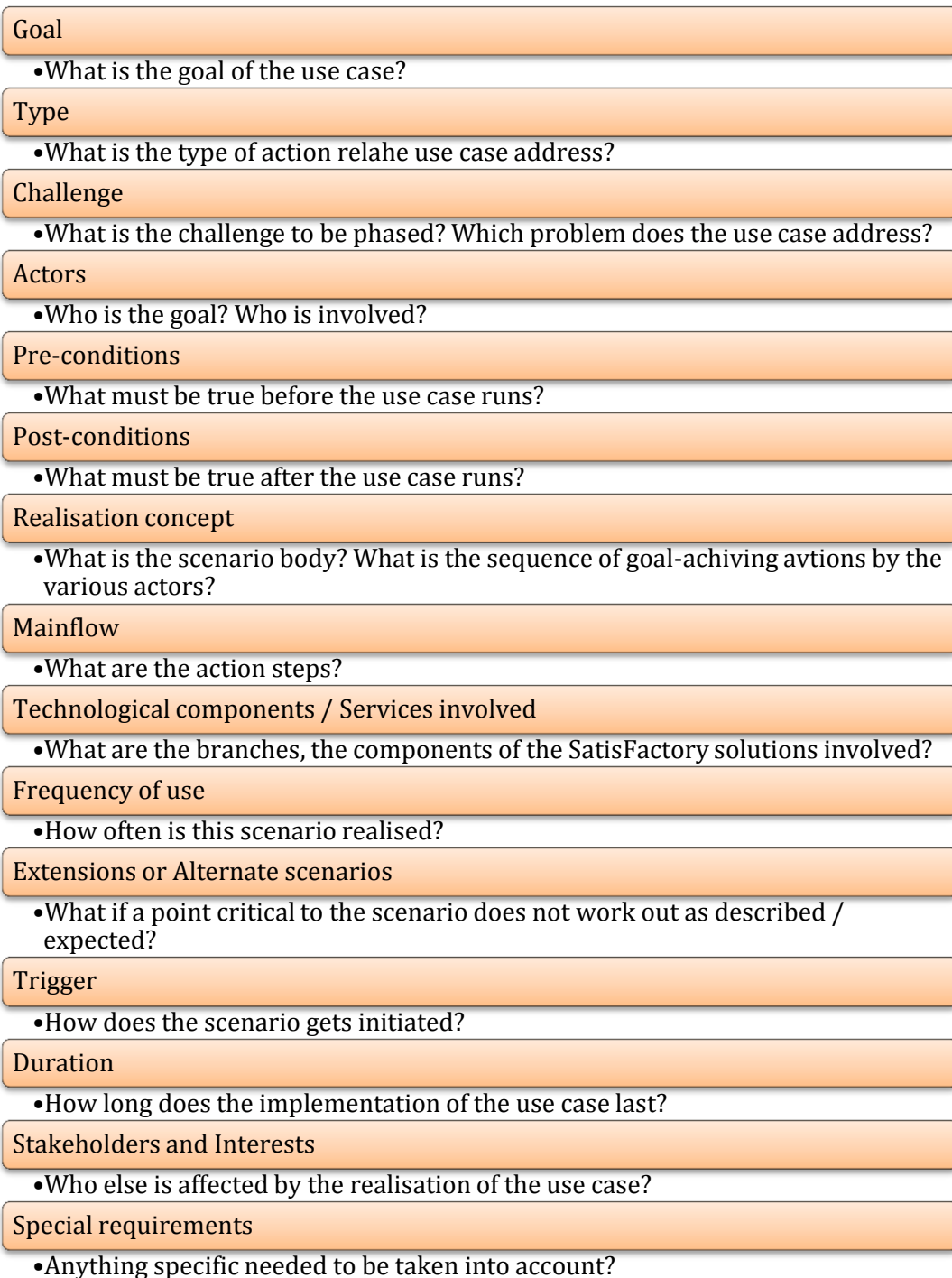


Figure 16 Breaking down the procedure description of the use case

The general concept derived from these two sources is applied to unify and simplify the description of the procedures at a high level. Moreover, the adopted consideration takes into account that different companies organize their functions according to their specific needs.

Thus, the **procedure description** of a use case should be comprised of a minimum set of information. According to Dr. Cockburn's approach, several questions need to be answered. What is the goal? Who is the goal? What must be true after the use case runs? And so on... It is necessary to break down the procedure description of the use case into questions that need to be answered, so that the scope behind it is clarified (Figure 16). It is noted that for the **definition of procedure types**, the approach of *EN 13306:2001: Maintenance terminology* has been adopted (Figure 17).

Rephrasing BS EN 13460:2002, in order to find out the kind of information necessary to perform a certain procedure, first of all, all the tasks have to be studied in detail. This information is, in some cases, absolutely necessary for the people involved in a task, so that they can perform it. In other cases, it provides the way to coordinate the individual tasks, functions, strategic planning and the means to measure, control and improve the function.

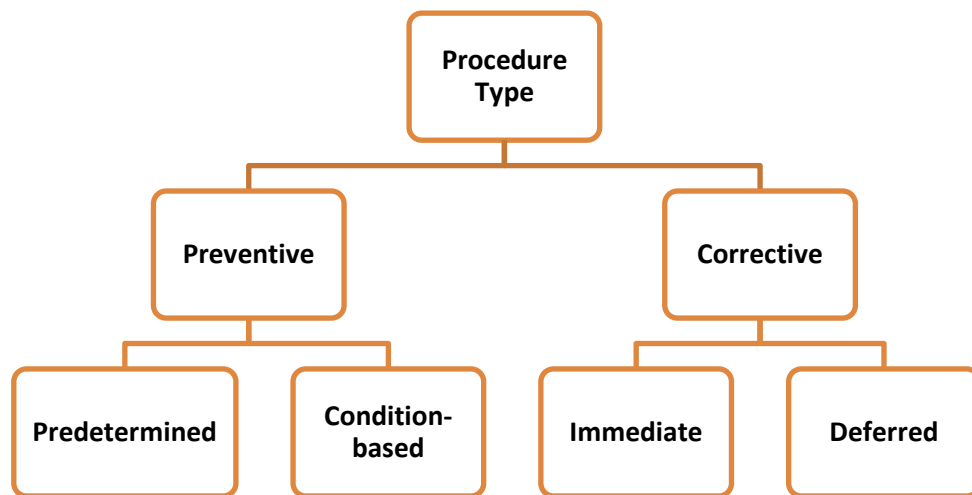


Figure 17 Categorisation of procedure types

The starting point of the analysis carried out to obtain the required documentation of information for maintenance, is the **"Main Flow"** or **"Workflow"**: a set of sequenced steps to be followed, in order to accomplish an operation, from the first preparatory activities, such as study and defining policies, to the analysis once the work is finished and action to be taken to improve future similar procedures. The Workflow is depicted in Figure 18. It is noted that the correct fulfilment of each one of the workflow steps requires the supply of certain information – input. Hence, each step of the workflow generates information – output, which will be necessary to carry out other steps. Each step should be as detailed as needed for easing the comprehension of the information which is there required and generated. It should be mentioned that the Work order (WO) is a document containing all the information related to an operation and the reference links to other documents necessary to carry out the respective work.

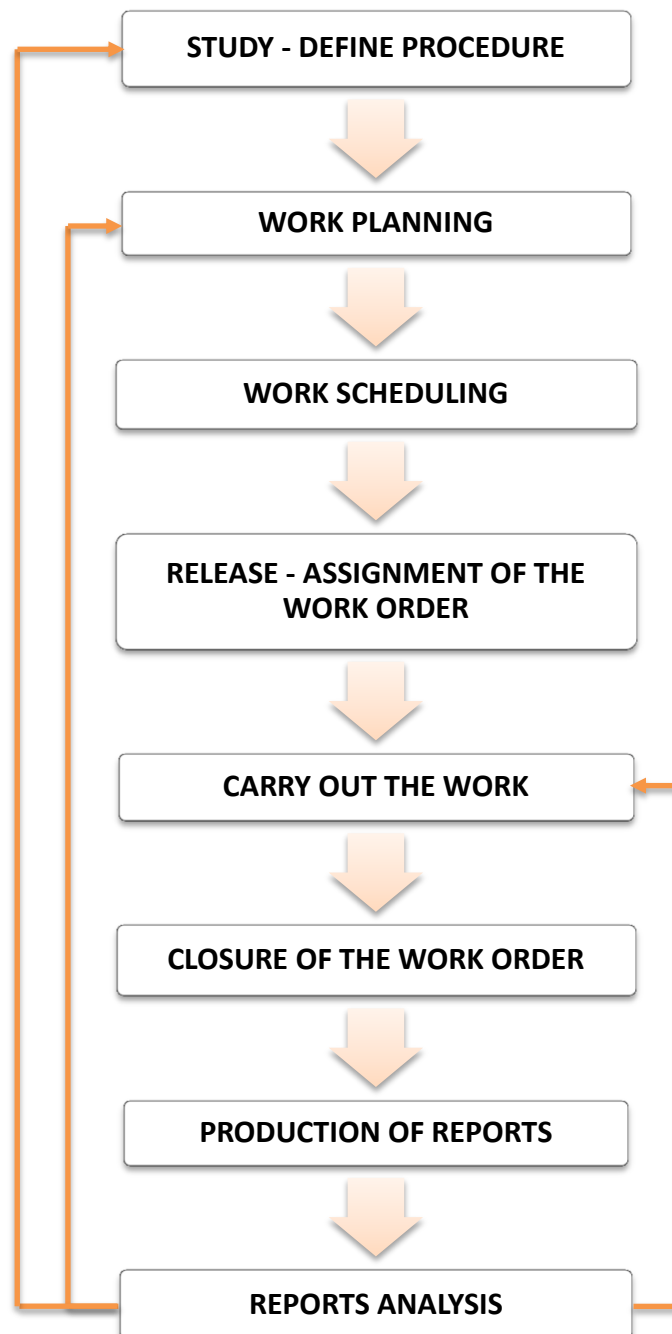


Figure 18 Workflow diagram

The overall concept described above was synthesized in a template followed in the description of the Application Scenarios at Chapter 5. Subsequently, the logic of the presented process is specified to an exact detailed use case and the Satisfactory Actors.

4.4 SATISFACTORY ACTORS

At this subsection the detailed characteristics of the groups of actors that are involved at the three shop floors are analysed using the template that was developed for this purpose. At each shop floor a number of groups of actors are identified and will play an important role to the realization of the use cases. These groups were initially identified at the activities of task 1.1 and were documented at deliverable “D1.1 User group definitions, end-user needs, requirement analysis and development guidelines”. At the present section the detailed analysis is presented for each user. For each shop floor a schematics that depicts the connection-hierarchy is presented.

4.4.1 Actors of COMAU’s shop floor

COMAU’s actors that will be considered in SatisFactory, are the roles devoted to the operation, as well as the design and engineering activities of the workplaces and ergonomics validations. COMAU’s actors that are involved at SatisFactory project belong at three categories based on their role and procedures that they perform. The relationship and the connection between these categories are depicted at Figure 19.

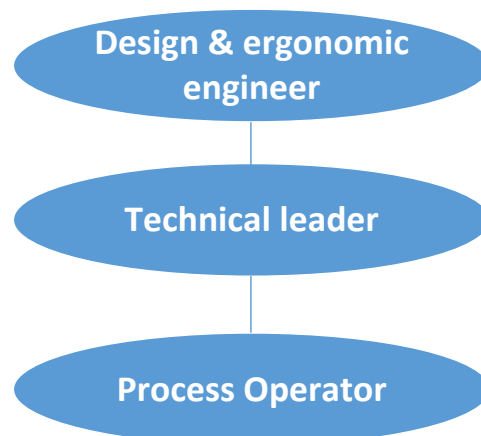


Figure 19 COMAU’s Actors’ interconnection diagram

The actors have been defined during first iteration of the deliverable and they have been validated during the preliminary implementations. At the following tables the tasks and expertise of the group of actors are analyzed for COMAU. For each of these categories a detailed analysis has been performed and the findings are documented on the basis of “Actors Template” (Table 9 Template for Actors’ description) that was presented in previous sections.

Table 10 COMAU Process Operator

Group Name	Process Operator
Category	Users

Demographical Data	Mostly men, heavy operations are required
Tasks	<ul style="list-style-type: none"> • mechanical assembly; • electrical wiring; • fluidics piping; • preliminary and final testing; • troubleshooting; • support to power-up and final delivery to customer (commissioning)
Expertize	<ul style="list-style-type: none"> • maintenance • mechanics • electrical installation • software programming (e.g. PLC, Robot programming)
Experience Level	Trainee, Novice, Experienced
Social Environment	collaboration with technical leaders, design engineers and other operators
Physical Environment	working area inside the shop floor
Aspects / Workflows	<ul style="list-style-type: none"> • according to the nature of the task, specialized operations have to be performed by skilled operators (e.g. electricians do not perform mechanical installation)

Table 11 COMAU Technical Leader

Group Name	Technical Leader
Category	Users
Demographical Data	Nothing special
Tasks	<ul style="list-style-type: none"> • technical design of machines and lines with dedicated team; • design team coordination; • external suppliers management; • ensuring the project progress according to milestones; • interfacing with workers employed in actual building of machinery in the shop floor
Expertize	<ul style="list-style-type: none"> • Project & Process Management • Maintenance • Welding Systems • Robotics • Mechanical Design • Electrical Design • Software programming (e.g. PLC, Robot programming)
Experience	Trainee, Novice, Experienced

Level	
Social Environment	Collaboration with all actors
Physical Environment	Mainly office, sometimes shop floor for inspections/tests
Aspects / Workflows	<ul style="list-style-type: none"> • coordinate/manage process operators • technical design of machines and lines with dedicated team • ensuring the project progress according to milestones

Table 12 COMAU Design & Ergonomics Engineer

Group Name	Design & Ergonomics Engineer
Category	Stakeholder
Tasks	<ul style="list-style-type: none"> • layout of machines design; • mechanical design; • electrical/software/hydraulic design; • ergonomics and safety issues; • preparation of drawings and diagrams for machinery and accessory parts construction
Expertize	<ul style="list-style-type: none"> • Project & Process Management • Welding Systems • Robotics Design • Mechanical Design • Electrical Design • Ergonomic Design • Laws and Norms compliance verification
Experience Level	Experienced
Social Environment	Collaboration with all actors, mainly technical leaders
Physical Environment	Mainly office, sometimes shop floor
Aspects / Workflows	<ul style="list-style-type: none"> • Interaction with customers/suppliers • Technical design of machines and lines • Ensuring the project progress according to milestones

4.4.2 Actors of SUNLIGHT's shop floor

The production plant of SUNLIGHT can be divided into four production lines and seven assembly lines, producing various types of batteries from industrial traction systems to consumer batteries.

Two of the assembly lines will be involved where various manual and automatic actions take place that transform the raw materials and components to a fully functional ready to use product. The first one is the Motive batteries (PzS) production line and the second one is the industrial type batteries (OPzS, OPzV) production line.

In both lines staff with different responsibilities are involved which are grouped into the following categories: Plant manager, Production planner, Production supervisors, Shop floor leaders and Workers (expert, novice). Also a technical/maintenance team (technicians, technical manager) is standby to correct if unplanned incidents occur. As the lines operate at 24/7 it is important for the various operations to be performed as smooth as possible. Also the immediate response and solution to malfunctions is critical in order to prevent delays in the production line.

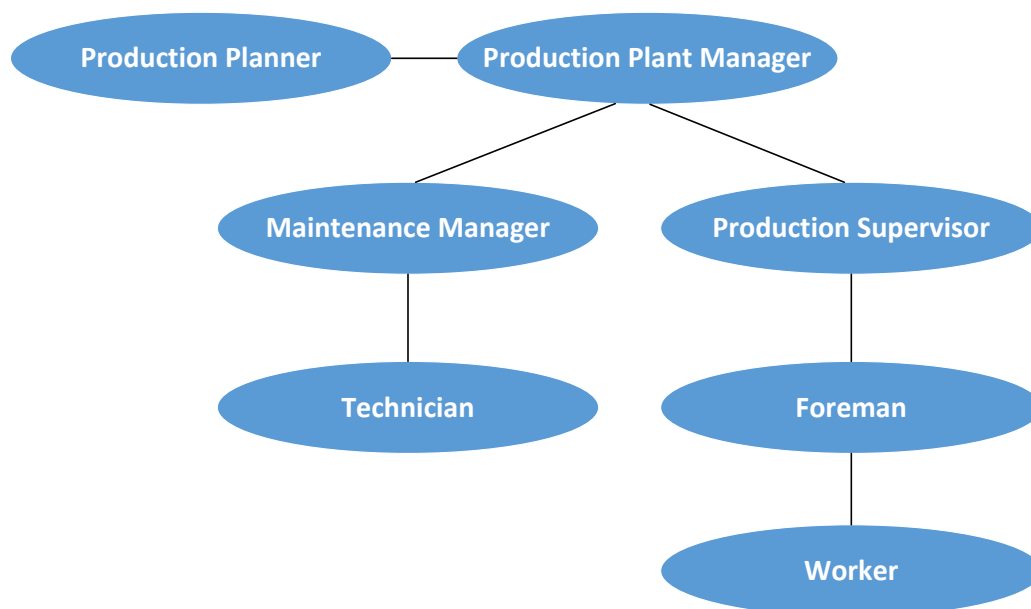


Figure 20 SUNLIGHT's Actors' interconnection diagram

Figure 20 shows that there are two main categories of actors; one related to the production and the other to the maintenance activities, whereas both are coordinated and supervised by the "Production Plant Manager". At the following tables the tasks and expertise of the groups of actors are analyzed for SUNLIGHT. For each of these categories a detailed analysis is performed and the findings are documented based on "Actors Template" (Table 9 Template for Actors' description) that was previously analyzed.

Table 13 SUNLIGHT Production Plant manager

Group Name	Production Plant manager
Category	Stakeholder
Demographical Data	None
Tasks	<ul style="list-style-type: none"> • Plan, organize, direct and run optimum day-to-day operations • Increase production, assets capacity and flexibility while minimizing unnecessary costs and maintaining current quality standards • Monitor operations and trigger corrective actions • Commit to plant safety procedures
Expertize	<ul style="list-style-type: none"> • Production manufacturing • Reducing waste • Raw material handling • Manufacturing quality • Technical skills • Project management skills • Organization and shift planning • Problem solving skills
Experience Level (optional)	Experienced
Social Environment	Collaboration with all actors
Physical Environment	Office, shop floors
Tools (optional)	Laptop
Aspects / Workflows (optional)	<ul style="list-style-type: none"> • Manage the production supervisors • Optimize the workflow of the shop floors

Table 14 SUNLIGHT Production planner

Group Name	Production planner
Category	Stakeholder
Demographical Data	None
Tasks	<ul style="list-style-type: none"> • Creates production schedule and prioritizes job-orders for production optimization. • Maintains the production schedule and other reports as required. • Interacts with shop floor management on a daily basis to resolve issues regarding manufacturing efficiencies or additional information as requested from Manufacturing, Customer Service and Accounting. • Ensure daily production requirements are achieved to meet customer expectation

	<ul style="list-style-type: none"> Analyze and prepare documents needed for production. Data analysis and decision making to support raw material supply and finished goods demand.
Expertize	<ul style="list-style-type: none"> Be able to make decisions quickly and sometimes under pressure. Have excellent organizational skills. Have excellent communication skills. Be comfortable working with figures. Be able to work quickly, accurately and pay attention to detail. Understand manufacturing processes. Be able to cope with deadlines and other pressured situations.
Experience Level (optional)	Experienced
Social Environment	Working with staff from other departments, such as the sales division, to understand the customer's exact requirements.
Physical Environment	Office, shop floors
Tools (optional)	Laptop
Aspects / Workflows (optional)	<ul style="list-style-type: none"> Communication with the customer service department

Table 15 SUNLIGHT Production supervisor

Group Name	Production supervisor
Category	Stakeholder
Demographical Data	None
Tasks	<ul style="list-style-type: none"> Managing and improving production processes to enhance product quality and maximize efficiency. Identifying problems or bottlenecks in the production processes. Planning, assigning, and directing production work. Organizing and prioritizing production needs. Directly supervising hourly production Creating an environment that is conducive to teamwork.
Expertize	<ul style="list-style-type: none"> leadership skills to motivate staff and manage a team ability to meet targets and deadlines good time management skills an approachable manner and good communication skills excellent problem-solving skills effective decision making skills Awareness of health and safety issues.
Experience Level	Experienced

(optional)	
Social Environment	Collaboration with other stake holders and user groups
Physical Environment	Office, shop floor
Tools (optional)	Laptop

Table 16 SUNLIGHT Foreman

Group Name	Foreman
Category	User
Demographical Data	Male only
Tasks	<ul style="list-style-type: none"> • Provide guidance and direction to the shop floor personnel. • Coordinate daily production floor activities and delegate assignments to production personnel. • Monitor employee work performance relative to expectations and maintain material/workflow through the facility. • Monitor employee work performance relative to expectations and maintain material/workflow through the facility. • Continuously evaluate and modify the plant layout and material workflow for increased throughput and productivity. • Fill out maintenance requests as necessary. • Monitor and enforce safety policies.
Expertize	<ul style="list-style-type: none"> • Being able to delegate responsibilities • Supervise and work with teams • Stress management and problem solving • Understanding blue-prints, sketches, and drawings
Experience Level (optional)	Experienced
Social Environment	Collaboration with other stake holders and user groups
Physical Environment	Office, shop floor
Tools (optional)	Laptop

Table 17 SUNLIGHT Worker

Group Name	Worker
Category	User

Demographical Data	Male only
Tasks	<ul style="list-style-type: none"> • Measuring, grading and feeding batches of raw materials into production machinery. • Operating production line equipment. • Assembling goods on a production line. • Reporting equipment faults to maintenance staff. • Finishing products. • Monitoring the production process and carrying out basic testing and quality checks. • Using lifting equipment and forklift trucks. • Cleaning and maintaining work areas and machinery.
Expertize	<ul style="list-style-type: none"> • good practical skills • ability to work quickly and methodically • good team working skills • ability to concentrate while doing repetitive tasks • ability to follow instructions • an awareness of health and safety • willingness to work flexibly
Experience Level (optional)	Novice or Experienced
Social Environment	Collaboration with other stake holders and user groups
Physical Environment	Shop floor
Tools (optional)	Shop floor machinery

Table 18 SUNLIGHT Maintenance Manager

Group Name	Maintenance Manager
Category	Stakeholders
Demographical Data	None
Tasks	<ul style="list-style-type: none"> • Designing maintenance programs • Researching for new equipment • Handling the training and development needs of new hires • Implementing preventative maintenance programs • Adhering to safety regulations • Enforcing industry requirements • Performing human resource responsibilities • Assessing risks • Managing expenditure and budgets
Expertize	<ul style="list-style-type: none"> • Managing maintenance budgets and controlling costs. • Root Cause Analysis. • Troubleshooting issues.

	<ul style="list-style-type: none"> • Awareness of modern maintenance techniques. • A good understanding of technical issues. • Superb leadership, coaching and mentoring skills. • Promoting a safety conscious working environment. • Knowledge of building codes, laws and regulations.
Experience Level (optional)	Experienced
Social Environment	Collaboration with other stake holders and user groups
Physical Environment	Office, shop floors
Tools (optional)	Laptop

Table 19 SUNLIGHT Technician

Group Name	Technician
Category	User
Demographical Data	Male only
Tasks	<ul style="list-style-type: none"> • Repair and maintain the operating condition of industrial production and processing machinery and equipment. • Repair and replace broken or malfunctioning components of machinery and equipment. • Record parts and materials used, and order or requisition new parts and materials as necessary. • Record repairs and maintenance performed.
Expertize	<ul style="list-style-type: none"> • Ability to manage stressful working situations • Ability to use tools and equipment for electrical or mechanical works • Electronics or/and Mechanical Troubleshooting • Analyzing Information • Judgment • Equipment Maintenance
Experience Level (optional)	Novice or Experienced
Social Environment	Collaboration with other stake holders and user groups
Physical Environment	Shop floor
Tools (optional)	Common and special tools for electricians and mechanics

4.4.3 Actors of CETH/CPERI's shop floor

The infrastructure of CETH/CPERI consists of numerous experimental industrial process units for the production of fuels, chemicals and evaluation of catalysts and feedstock of the petrochemical industry where various group of users work at a daily basis. The analysis that was performed at D1.1 revealed that eight group of users (actors) will be involved the project.

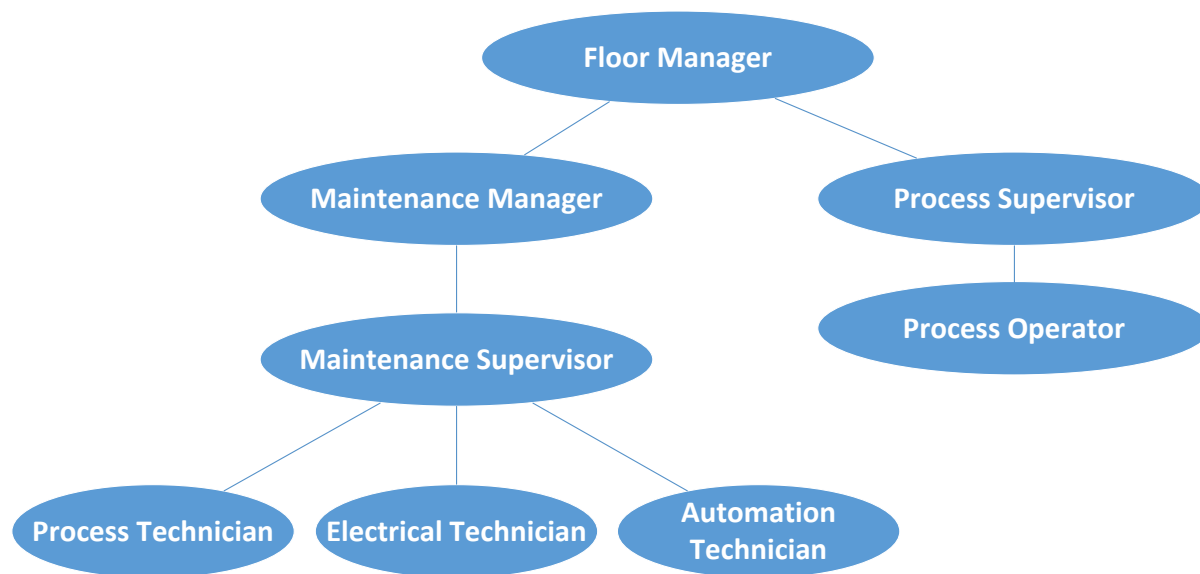


Figure 21 CETH/CPERI's Actors' interconnection diagram

Figure 21 shows that there are two main categories of actors; one related to the process operations and the other to the maintenance activities, whereas both are coordinated and supervised by the "Floor Manager". Furthermore, the maintenance team is divided into three categories of groups according to the area of expertise, namely the mechanical-process, the electrical, and the automation related group. At the following tables the tasks and expertise of the group of actors are analyzed for CETH/CPERI. For each of these categories a detailed analysis is performed and the findings are documented at "Actors Template" (Table 9 Template for Actors' description) that was previously analyzed.

Table 20 CETH/CPERI Floor Manager

Group Name	Floor Manager
Category	Stakeholders
Tasks	<ul style="list-style-type: none"> decision making and decision support for allocation of resources at existing processes overall supervision on the workflow of the shop floor
Expertize	<ul style="list-style-type: none"> good knowledge on chemical processes management of human resources

	<ul style="list-style-type: none"> administrative skills
Experience Level	Experienced
Social Environment	collaboration with all actors
Physical Environment	office
Aspects / Workflows	<ul style="list-style-type: none"> able to organize and inspect the general workflow of the shop floor collaboration skills with other stakeholders continuous optimization of the workflow of the shop floor

Table 21 CETH/CPERI Process Supervisor

Group Name	Process Supervisor
Category	Stakeholders
Tasks	<ul style="list-style-type: none"> share of information about daily experiments and processing of data from the field and the laboratory analysis schedule new constructions or system revamps
Expertize	<ul style="list-style-type: none"> experience on chemical processes excellent knowledge of Pilot Plants operation good knowledge of using process monitoring systems administrative skills
Experience Level	Experienced
Social Environment	collaboration with all actors
Physical Environment	office and pilot plant control room
Aspects / Workflows	<ul style="list-style-type: none"> responsible for the operation of the pilot plants manage process operators

Table 22 CETH/CPERI Maintenance Manager

Group Name	Maintenance Manager
Category	Stakeholders
Tasks	<ul style="list-style-type: none"> sharing of programmed actions be informed about existing work in progress and involvement of technical team schedule new constructions or system revamps

Expertize	<ul style="list-style-type: none"> • able to organize tasks on the shop floor • collaboration skills with other stakeholders • automation, electrical and mechanical knowledge
Experience Level	Experienced
Social Environment	collaboration with all actors
Physical Environment	office and inside the shop floor area
Aspects / Workflows	<ul style="list-style-type: none"> • keep the general view of the shop floor on high levels • able to have good collaboration with other stakeholders

Table 23 CERTH/CPERI Maintenance Supervisor

Group Name	Maintenance Supervisor
Category	Stakeholders
Tasks	<ul style="list-style-type: none"> • sharing of programmed actions • be informed about existing work in progress and involvement of technical team
Expertize	<ul style="list-style-type: none"> • able to coordinate the technical users • collaboration skills with other stakeholders and user groups • automation, electrical and mechanical knowledge
Experience Level	Experienced
Social Environment	collaboration with all actors
Physical Environment	office and inside the shop floor area
Aspects / Workflows	<ul style="list-style-type: none"> • keep the general view of the shop floor on high levels • able to have good collaboration with other stakeholders • knowledge about all technical issues about the shop floor and the operation of the pilot plants • able to respond fast and efficient to incidents and unplanned situations

Table 24 CETH/CPERI Process Technician

Group Name	Process Technician
Category	Users
Demographical Data	male only for positions where handling of heavy equipment is required
Tasks	<ul style="list-style-type: none"> • Preserve information related to performed procedures • Support and maintain Pilot plants operation • Involved in new constructions and revamps
Expertize	<ul style="list-style-type: none"> • good knowledge of mechanical design software such as AutoCAD Mechanical • able to use tools for construction of Pilot Plants such as electric winding, electric drills and all electric tools
Experience Level	Trainee, Novice, Experienced
Social Environment	collaboration with all stakeholders and other user groups
Physical Environment	working area inside the shop floor, the machine shop, the calibration room
Aspects / Workflows	<ul style="list-style-type: none"> • able to respond fast and efficient to incidents and unplanned situations • able to handle immediate and crucial malfunctions, able to organize scheduled actions in order not to interrupt the normal operation of the shop floor • handles process supervisors' and process operators' queries on not scheduled tasks, cooperate with maintenance managers and supervisors to schedule the maintenance tasks

Table 25 CETH/CPERI Control, Automation, IT Technician

Group Name	Control, Automation, IT Technician
Category	Users
Demographical Data	nothing special
Tasks	<ul style="list-style-type: none"> • Design information (P&ID, mechanical drawings) • Preserve information related to performed procedures • Maintaining IT structures • Involved in new constructions and revamps
Expertize	<ul style="list-style-type: none"> • experience on SCADA and automation software • very good knowledge on IT infrastructures, Windows based programs • able to communicate and cooperate with other user groups
Experience Level	Trainee, Novice, Experienced

Social Environment	collaboration with all stakeholders and other user groups
Physical Environment	working area inside the shop floor and almost in all places that have SCADA or/and IT equipment
Aspects / Workflows	<ul style="list-style-type: none"> • able to respond fast and efficient to incidents and unplanned situations • able to handle immediate and crucial malfunctions • able to organize scheduled actions in order not to interrupt the normal operation of the shop floor • handles process supervisors' and process operators' queries on not scheduled tasks • cooperate with maintenance managers and supervisors to schedule the maintenance tasks

Table 26 CERTH/CPERI Electrical Technician

Group Name	Electrical Technician
Category	Users
Demographical Data	nothing special
Tasks	<ul style="list-style-type: none"> • design information (P&ID, electrical schematics) • preserve information related to performed procedures • support and maintain Pilot plants operation • involved in new constructions and revamps
Expertize	<ul style="list-style-type: none"> • good knowledge and experience on high and low voltage electrical systems • able to understand electrical schematics and manuals • good knowledge of electrical design software such as AutoCAD Electrical
Experience Level	Trainee, Novice, Experienced
Social Environment	collaboration with all stakeholders and other user groups
Physical Environment	working area inside the shop floor, the machine shop, the calibration room
Aspects / Workflows	<ul style="list-style-type: none"> • able to respond fast and efficient to incidents and unplanned situations • able to handle immediate and crucial malfunctions • able to handle immediate and crucial malfunctions • handles process supervisors' and process operators' queries on not scheduled tasks • cooperate with maintenance managers and supervisors to schedule the maintenance tasks

Table 27 CERTH/CPERI Process Operator

Group Name	Process Operator
Category	Users
Demographical Data	nothing special
Tasks	<ul style="list-style-type: none"> • Perform Daily operations • Report about malfunctions or abnormal operation of equipment or systems • Organizing raw materials for the experiments on the Pilot Plants
Expertize	<ul style="list-style-type: none"> • experience on chemical processes • usage of hydraulic and pneumatic systems • good knowledge of safety measures on Pilot Plants operation • good knowledge of using process monitoring systems
Experience Level	Trainee, Novice, Experienced
Social Environment	collaboration with process supervisors and other user groups
Physical Environment	working area inside the shop floor and inside the pilot plant control room
Aspects / Workflows	<ul style="list-style-type: none"> • able to operate the pilot plants with efficiency and fast response to incidents and unplanned situations • able to recognize malfunctions and abnormal situations regarding the Pilot Plants

4.4.4 Connection of Actors with Application Scenarios & Use Cases

The aforementioned groups of actors are used at each Application Scenario (Chapter 5) and at the Use Cases (Chapter 6). These groups refer to the workers at the involved shop floor which are necessary for the implementation of the Application Scenarios. Depending on the Application Scenario and the Use Case one or more groups of actors are involved. The detailed analysis from Chapter 4 assists to the engagement of the appropriate actors that will use the SatisFactory platform. The following table presents the connection of the groups of actors with the Application Scenarios.

Table 28 Connection between Application scenarios and groups of actors at SatisFactory

Application scenarios	Actors							
	Managers and engineers		Supervisors			Operators & Technicians		
	Design & ergonomic engineer	Maintenance Manager	Maintenance Supervisor	Production/Process Supervisor	Foreman	Process Operators	Production Line Workers	Maintenance/Electrical/Process/Control Technicians
BSC-1.1						√		
BSC-1.2						√		
BSC-2.1	√					√		√
BSC-3.1					√		√	√
BSC-4.1				√	√		√	
BSC-4.2				√			√	
BSC-4.3					√		√	
BSC-5.1			√	√		√		
BSC-5.2			√	√		√		√
BSC-5.3		√		√		√		√
BSC-6.1		√	√	√		√		√

The following table is presenting another view of the participation of the groups of actors at the SatisFactory Project. It presents the participation of each of the Actors' groups at the Use Cases of SatisFactory.

Table 29 Connection between Use Cases and groups of actors at SatisFactory

Use Cases	Actors			
	Managers and engineers	Supervisors	Operators & Technicians	Event
UC-1.1			√	√
UC-1.2			√	
UC-1.3			√	
UC-2.1		√	√	
UC-2.2			√	
UC-2.3			√	
UC-3.1			√	
UC-3.2		√	√	
UC-3.3		√		
UC-3.4			√	
UC-4.1			√	
UC-4.2		√	√	
UC-4.3	√	√	√	
UC-4.4	√	√	√	
UC-4.5				√
UC-5.1		√	√	
UC-5.2		√	√	
UC-5.3		√	√	
UC-5.4		√	√	
UC-6.1		√	√	
UC-6.2			√	
UC-6.3		√	√	
UC-6.4		√	√	

5 SATISFACTORY BUSINESS SCENARIOS

The aim of this chapter is to describe the Business Scenarios that have been identified for testing the development of the SatisFactory project. There have been various updates since the 2nd iteration of the chapter of the Deliverable D1.2. At the current document, which is the third and final version of the Deliverable D1.2, there are the final descriptions of the BSCs for the three shop floors. All the Business Scenarios have been revised according to the needs of each end user (COMAU, SUNLIGHT, CERTH) and according to the feasibility and the functionality of the SatisFactory components. During the first and the second iteration of the Deliverable D1.2 some functions of the components and needs of the users at the shop floors were preliminary defined. As the project progressed from the design to the implementation phase, each partner understood better the scope of the project and the contribution that he had to this scope. Therefore, the revision of the Application and Business Scenarios was necessary in order to clarify and improve the envisioned shop floor.

These Scenarios have been originated from the three end users (COMAU, SUNLIGHT, CERTH) and each one targets different aspects of the operations and activities that take place at the shop floor with respect to the workers involvement and collaboration. The contribution of this Chapter is twofold. Initially the generic context of operations is described and secondly a detailed analysis through specific Application Scenarios is presented. The initially identified Application Scenarios cover a wide range of operating activities and resemble the actual working activities at each shop floor by including not only the nominally operating procedures but also those that handle abnormal situations or maintenance related activities, planned or unplanned. Through the SatisFactory platform the involved groups of workers will benefit in term of knowledge sharing, collaboration, effective time handling, on the job training and online information about incidents or issues at the shop floor.

The identification and the definition of the BSCs and the UCs (see Chapter 6) are the basis and motivation for the demonstration of the SatisFactory developments. This chapter presents the high-level business scenarios from the involved shop floors and the detailed use cases that cover the desired functions of the SatisFactory platform. Taking into account the user needs and requirements, the objectives of the project and the end-users activities at the shop floors a number of business scenarios are documented and are implemented by a set of UCs. The scenarios address the perspectives of different involved actors at the discrete manufacturing (COMAU, SUNLIGHT) and continuous process environments. The selected Business Scenarios that are supported by the SatisFactory platform can be divided in three different groups, based on the involved shop floors.

Overall the identified BSCs cover operations and activities that can be categorized as follows:

- **Real-time support activities**
 - Repair or restore malfunctions (unexpected failures or planned maintenance)
 - Real time identification and response of abnormal events of equipment operating in a controlled environment (informative decision making and knowledgeable actions)
 - Startup procedures for pilot plants (real-time information and knowledgeable actions)
- **Event and Incident logging**

- Notification based on localization of workers and proximity to unauthorized areas
- Reconfiguration of process flow and actions for flexible redesign of production procedures (interaction between actors and historical data from the automation systems)
- Recognition of incidents involving workers and equipment on the shop floor (safety related issues)
- **Learning & Collaboration environment**
 - Process operators (fast training of the process operators at process units)
 - Technicians (fast and effective training of the technical team)
 - Enhanced collaboration with social inter-factory communication (for optimum engagement at shop floor activities) utilizing gamification procedures

The BSCs and UCs represent the dynamic analysis of the shop floor that presents the way that the involved systems will actually work during the daily performed activities. The Use Cases represent the functionalities of the system and have the potential to be utilized by more than one Business Scenarios. A summarized list of the SatisFactory high level Business Scenarios is presented (Table 30).

Table 30 List of Business Scenarios and Application Scenarios

Business Scenario	Application Scenario	Name
BSC-1	Operation activities of machine assembly at manufacturing procedures (COMAU)	
	BSC-1.1	Manual assembly operations with focus on Robot Wrist assembly
	BSC-1.2	Automated assembly operations with focus on Welding Gun assembly
BSC-2	Support of the components of production lines for intermittent operation (COMAU)	
	BSC-2.1	Remote Assistance
BSC-3	Knowledge enabled support of systems and workforce for semi-automated battery assembly lines (SUNLIGHT)	
	BSC-3.1	Preventive and corrective maintenance management system
BSC-4	Monitoring and learning activities at battery production lines (SUNLIGHT)	
	BSC-4.1	Motive power battery assembly line
	BSC-4.2	Monitoring of the Cell Temperature during Jar formation and data collection
	BSC-4.3	Training platform for production process motive power batteries assembly line
BSC-5	Online supervision of the operation and workforce resources of pilot plants for chemical processes (CERTH)	
	BSC-5.1	Repair or restore an electromechanical malfunction

BSC-5.2	Startup procedures for pilot plants
BSC-5.3	Reconfiguration of process flow and actions for flexible redesign of production procedures
BSC-6	Recognition of incidents and path optimization for workers' movement (CERTH)
BSC-6.1	Recognition of incidents and path optimization for workers movement on the shop floor

At the subsequent section of this Chapter a detailed analysis of the Application Scenarios for each Business Scenario will take place. The Application Scenarios described in this chapter have been identified with the primary objective of motivating concepts and innovations expected through SatisFactory project, in order to address existing issues or barriers related to the knowledge sharing and the collaboration of actors among the various locations at the shop floor. Also, these Application Scenarios have been selected to better highlight the functional and nonfunctional requirements of the SatisFactory architecture and the developed SatisFactory platform. Besides the narrative description of the main points of each Business Scenario, a template was used to document the important aspects of each Application Scenario. Figure 22 shows the hierarchy of the Business Scenarios and the Application Scenarios per end user.

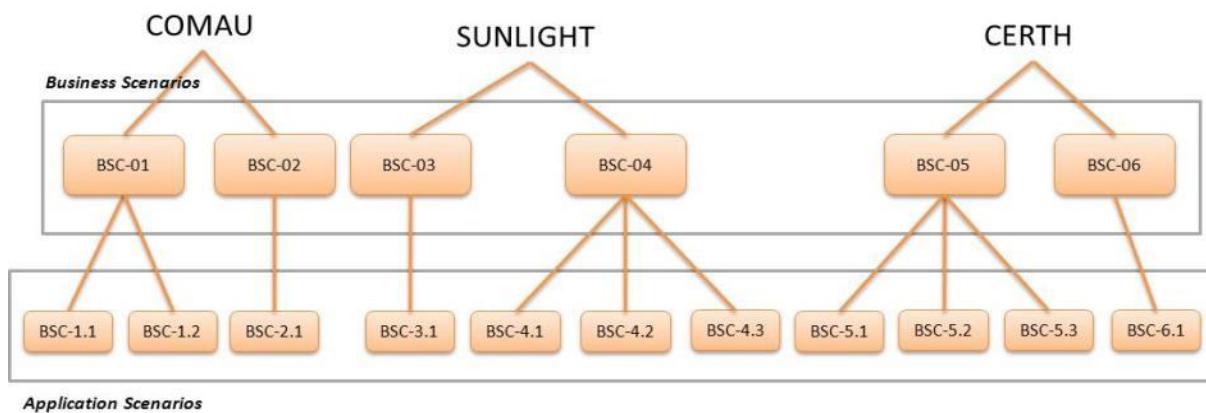


Figure 22 Hierarchy of Business Scenarios and Application Scenarios per end user

5.1 TEMPLATE FOR APPLICATION SCENARIOS

There are no standard templates for describing Application Scenarios and a way of defining a single template that is effective for all application domains. Nevertheless, the SatisFactory partners have decided to adopt the template which is presented at the following table. The approach also covers some general guidelines available in the literature.

Table 31 Template for Application Scenarios

Application Scenario #	<i>Please enter an Application Scenario ID</i>
Application Scenario Name	<i>Please enter an Application Scenario name</i>
Version/Author	<i>Stage the Application Scenario has reached / Who documented the Application Scenario</i>
Goal	<i>Determine the goal of Application Scenario</i>
Type	<i>Please describe the type of actions involved in the Application Scenario based on the following categories:</i> 1. Preventive actions: Condition based (scheduled, continuous, on request) or Predetermined (scheduled) 2. Corrective actions: Deferred or Immediate
Challenges	<i>Please identify the challenges that exist today that the Application Scenario implementation will overcome</i>
Involved Actors	<i>Define the actors involved in the Application Scenario. The same actor may play two different roles in the same Application Scenario.</i>
Pre-conditions	<i>Preconditions specify the conditions that must hold true before the scenario starts and will not be checked again after that.</i>
Post-conditions (Minimal Guarantees, Success Guarantees, Failure end conditions)	<i>Minimal Guarantees specify what at least must hold true in case neither the main success scenario nor any alternate route has successfully finished.</i> <i>Success Guarantees specify what must have been achieved at the end of the main success scenario or any alternate route.</i> <i>Failure end conditions of the Application Scenario indicates if the Actor's goal(s) have not been achieved</i>
Realization Concept	<i>How should the Application Scenario be realized in the SatisFactory system?</i>
Brief Description / Main flow	<i>Please describe the series of steps for the defined Application Scenario in a clear concise manner. Include in the description what the SatisFactory system shall do for the involved actor to achieve a particular goal.</i> <i>This section shall describe the typical course of events using a step-based approach based on the following:</i> <ol style="list-style-type: none"> 1. Study – Define, Preventive – Corrective Maintenance Operations 2. Work Planning 3. Work Scheduling 4. Release – Assignment of the Work Order 5. Carry Out the Work 6. Closure of the work 7. Production of Reports 8. Reports Analysis
Frequency of use	<i>Exists only for Scheduled type actions and indicates the frequency of the performed action(s). In case of Corrective action(s) remains Not Applicable</i>
Extensions or Alternate scenarios	<i>An exception is documented by specifying an alternate route in the scenario, which is called an extension (related to, but not the same as an extension Application Scenario, which will be discussed later on)</i>
Trigger	<i>The event or sequence of events that initiate the Application Scenario</i>

Duration	<i>Indicates the duration of the carried out action(s)</i>
Stakeholders and Interests	<i>Indicates the various stakeholders who may not directly interact with the system but they may have an interest in the outcome of the Application Scenario</i>
Special requirements (e.g. Performance, Security, safety, user interface requirements etc.)	<i>Indicate any other requirements valid specific only on some Application Scenarios</i>

The next sections present the core descriptions of each use case broken down in steps involving the field description and the main flow. The steps in main flow represent the most typical sequence of events. Alternative flows are introduced when a given step allows for multiple successive steps. Alternative flows can occur through different human decisions or different combinations (if any) of the features involved leading to different flows/steps. Exception flows are introduced when the sequence of steps prevents the achievement of a set goal (either on privacy or security). Both alternative and exception flows are linked to the main flow of events by clearly stating on what step the variation commences.

5.2 BUSINESS SCENARIOS AT AUTOMOTIVE MANUFACTURING SHOP FLOOR (COMAU)

COMAU is a global supplier of industrial systems and services mainly for the automotive manufacturing sector that produces several standardized products used by other business units to be integrated in various production systems according to customer requirements. The Business Scenarios identified for the SatisFactory project will involve the production of such standard components.

5.2.1 BSC-1 - Operation activities of machine assembly at manufacturing procedures (COMAU)

The first BSC that will be explored through the development of specific Application Scenarios at COMAU's shop floor will focus mainly on the production lines related to the operations that are necessary for the mechanical assembly and the manual assembly of components such as a robotized arm or a welding gun. There are two application scenarios involved that cover a subset of activities that are performed at daily basis at the shop floor of COMAU:

- BSC-1.1 Manual assembly operations with focus on Robot Wrist assembly
- BSC-1.2 Automated assembly operations with focus on Welding Gun assembly

5.2.1.1 BSC-1.1 Manual assembly operations with focus on Robot Wrist assembly

The first Application Scenario (BSC-1.1) at COMAU is related with the operations and procedures that are performed at the shop floor for the assembly of a robot arm, including the wiring and its cabinet configuration. This assembly process is completely manual and it is divided in specific steps each one performed in a specific assembly workplace. During the week, according to workload and operators availability, the workers could rotate in the different assembly stations, thus performing different

operations. SatisFactory actions in this environment envisage the development of a sensorized workplace, including user interface that could run on a fixed (A.R. HMI) or mobile (A.R. Glasses) terminal. This system will continuously guide the operator providing contextual information in the assembly operations and monitoring the steps performed. The scenario applies both to training and operation phases. The final product of the following operation will be the COMAU Robotized Arm, as shown in the figure below:



Figure 23 COMAU Robot



Figure 24 COMAU Final assembly of the robot arm

Table 32 COMAU Application Scenario 1 characteristics

Application Scenario #	BSC-1.1
Application Scenario Name	Manual assembly operations with focus on Robot Wrist assembly
Version/Author	v02 / P. Cultrona (COMAU)
Goal	Mechanical assembly of the robotized arm. Share knowledge.
Type	Predetermined (scheduled)
Challenges	Reduce assembly faults by increasing both ergonomics and worker satisfaction. Ease training activities. Access hidden knowledge about processes of workers and make it available for other workers. Provide positive feedback if provided knowledge was needed.
Involved Actors	Process Operator
Pre-conditions	Product demand Resources availability
Post-conditions (Minimal Guarantees, Success Guarantees, Failure end conditions)	Minimal Guarantees: Production performed within the expected cycle time. Knowledge about process could be documented. Success Guarantees: Production performed within the expected cycle time and minimum or no scrap. Worker used knowledge about process that was provided by other workers, who will receive feedback that his provided knowledge was used.

	Failure end conditions: Production loss due to defective products or wrong assembly operations. Worker frustrated or injured.
Realization Concept	The system should provide information about the process conditions and information about the assembly operations to be performed. The appropriate information about the tools, components and the respective operations should be automatically provided through HMIs. During task execution, workers can request knowledge or provide new knowledge about the task to a central knowledge repository.
Brief Description / Main flow	<p>The operations are performed by Process Operators and they consist in specific mechanical activities such as:</p> <ul style="list-style-type: none"> • cleaning of the mechanical parts coming from foundry/machining • gears and spacers assembly • sealing and grease filling • test of tolerances & mechanical couplings • finally marking electrical motors & wiring assembly <p>If workers stumble upon a problem during the execution they can access the knowledge base for searching for help using an HMI at the workplace. If the requested knowledge has led to a solution, the worker confirms this. In the same way, workers can access the knowledge base during the execution of a task to add new knowledge. The worker who has provided the knowledge receives feedback that his knowledge was used.</p> <p>At the end of the assembly activities, specific reports have to be provided by the operators. According to feedbacks collected through sensors the SatisFactory platform should be able to elaborate automatically production reports and checklist.</p>
Frequency of use	8 h/d (5 d/w). The knowledge exchange platform can also be used for other tasks or other application scenarios
Extensions or Alternate scenarios	Extension: Provided knowledge can be rated by co-workers. If rated good, this is additional positive feedback for the knowledge provider
Trigger	Production Schedule, knowledge repository access is triggered by workers
Duration	Depending on the Production Cycle Time
Stakeholders and Interests	<p>Technical Leader: interested in production milestones achievements</p> <p>Design & Ergonomics Engineer: Respectively involved in production and ergonomics for workplace designing</p>
Special requirements	<p>If applied in production, a specific analysis of ergonomics factors has to be taken into account.</p> <p>In order to allow assembly activities both hands are required so fixed terminals or glasses are preferred instead of, for instance, mobile tablets.</p>

5.2.1.2 BSC-1.2 Automated assembly operations with focus on Welding Gun assembly

The second Application Scenario (BSC-1.2) presented by COMAU is related to the welding gun assembly. The assembly process is moving from a completely manual operation to a fully automated process. Main challenge here is to operate in a “brown field” (i.e. an already existing facility), where automation components such as PLC, HMI etc. are already in place and the SatisFactory components and modules should be able to interface with the existing hardware. This scenario, as the previous one applies both to training and operation phases. The welding gun of COMAU and some indicative information are shown at the following figures.



Figure 25 COMAU Welding gun

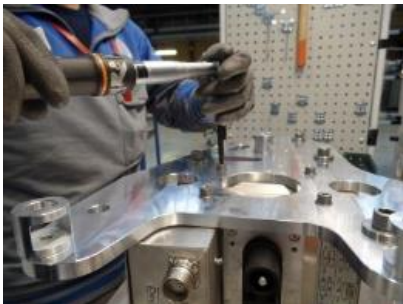


Figure 26 COMAU welding gun body assembly (a)

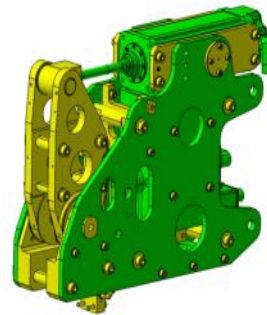


Figure 27 COMAU Welding gun body

For BSC-1.2 the involved workers can use various documents. More specifically Process Operators have access to the following categories of documents during mechanical assembly:

1. Assembly procedures, either standard or learnt during training phase (mainly doc, pdf, ppt, xls)
2. Safety and ergonomics procedures (demonstration during training; pdf, doc, video)
3. Mechanical drawing (cad files, such as dxf, dwg)
4. Checklists (doc, xls, pdf)

Table 33 COMAU Application Scenario 2 characteristics

Application Scenario #	BSC-1.2
Application Scenario Name	Automated assembly operations with focus on Welding Gun assembly
Version/Author	v01 / P. Cultrona (COMAU)
Goal	Perform manual assembly of a spot welding gun.
Type	Predetermined (scheduled)
Challenges	Reduce assembly faults by increasing both ergonomics and worker satisfaction. Ease training activities.
Involved Actors	Process Operator
Pre-conditions	Product demand Resources availability
Post-conditions (Minimal Guarantees, Success Guarantees, Failure end conditions)	Minimal Guarantees: Production performed within the expected cycle time. Success Guarantees: Production performed within the expected cycle time and minimum or no scrap. Worker satisfied. Failure end conditions: Production loss due to defective products or wrong assembly operations. Worker frustrated or injured.
Realization Concept	The system should provide information about the process conditions and information about the welding gun assembly operations to be performed. The appropriate information about the tools, components and the respective operations should be automatically provided through HMIs.
Brief Description / Main flow	The welding gun assembly process is performed by Process Operators and involves the following activities: <ul style="list-style-type: none"> • preparation of the mechanical structure of the body with the transformer • integration of the arms with the copper tips holders and the linear motor • wiring and piping installation • testing and certification (fine tuning of the welding parameters)
Frequency of use	8 h/d (5 d/w)
Extensions or Alternate scenarios	-
Trigger	Production Schedule
Duration	Depending on the Production Cycle Time
Stakeholders and Interests	Technical Leader: interested in production milestones achievements Design & Ergonomics Engineer: Respectively involved in production and ergonomics for workplace designing

Special requirements	If applied in production, a specific analysis of ergonomics factors has to be taken into account. In order to allow assembly activities both hands are required so fixed terminals or glasses are preferred instead of, for instance, mobile tablets.
----------------------	--

5.2.2 BSC-2 - Support of the components of production lines for intermittent operation (COMAU)

The second Business Scenario deals with activities that support the operations that take place at COMAU'S shop floor. Maintenance is an important aspect in the life of a production system. In order to ensure the proper working conditions periodic check activities must be performed and some components must be replaced due to wearing in normal operations. An indicative figure that shows the environment at COMAU's shop floor is shown at the following figure.



Figure 28 COMAU working environment

COMAU does not perform maintenance operations directly, but provides to its customers specific procedures describing the main maintenance operations to be performed and their scheduling. Sometimes in case of critical faults, COMAU engineers are required to interface with customer's maintenance staff in order to fix faults. The Application Scenario that could apply both to training and operation phases is "BSC-2.1 Remote Assistance at manufacturing production lines".

5.2.2.1 BSC-2.1 Remote Assistance at manufacturing production lines

Table 34 COMAU Application Scenario 3 characteristics

Application Scenario #	BSC-2.1
Application Scenario Name	Remote Assistance at manufacturing production lines
Version/Author	v02 / P. Cultrona (COMAU)
Goal	Provide remote assistance for maintenance operations. Provide additional training possibilities from co-workers.
Type	Upon request

Challenges	Reduce the MTTR by increasing both ergonomics and worker satisfaction. Ease fault restoring helping involved personnel with useful information Access hidden training skills of workers and make it available for other workers. Provide possibility for live guidance
Involved Actors	Process Operators, Maintenance Staff, Design Engineers
Pre-conditions	Line fault On-site maintenance staff, remote engineers availability
Post-conditions (Minimal Guarantees, Success Guarantees, Failure end conditions)	Minimal Guarantees: Fault restoration. Training data stored. Success Guarantees: Fault restoration in very short time avoiding production loss. Workers satisfied. Live assistance and training from co-workers led to solving the problem. Failure end conditions: Production loss due to long time required for fault restoration.
Realization Concept	The system should provide a platform that allows maintenance staff working in the shop-floor to request assistance in critical conditions from experts and design engineers working in the office, showing the problem by means of cameras and receiving support through smart glasses or other smart devices (tablets, smartphones) integrating augmented reality features. Workers can indicate their availability for training for a certain task in a repository. When other workers are in need of help, they can check this repository and connect to the training provider for remote assistance.
Brief Description / Main flow	<ul style="list-style-type: none"> • Maintenance technician has to perform a planned maintenance intervention based on Her / His work schedule; • She / He reaches for intervention target; • She / He starts a maintenance intervention procedure with multi-format support (markerless Augmented Reality, immersive Virtual Reality, videos, pictures, documentation ranging from PDF manuals to drawings); • In case of troubles in task execution She / He can ask for a technical support expert starting a call; • During the call there would be the possibility of sharing pictures bi-directionally, of receiving multi-format documentation on maintenance technician side and, more important, to stream video form Shop Floor to remote support technician • On Her / His side technical assistance expert can – in the best case – add information (text or hand-drawn instructions) that will be then real-time displayed on maintenance technician side in Augmented Reality
Frequency of use	8 h/d (5 d/w)
Extensions or Alternate scenarios	Extension: Also asynchronous training can be offered. For instance, workers can upload training videos for a particular task. This video can be found by other workers in the training repository and viewed even in times when the training provider is not available
Trigger	Line fault. Knowledge repository access is triggered by workers

Duration	Depending on the fault complexity
Stakeholders and Interests	Process operator/maintenance staff: to improve their work efficiency reducing their workload and stress (by means of remote support) Design Engineer: Able to get quickly feedbacks and providing support in case of production problems
Special requirements	A specific analysis of ergonomics factors has to be taken into account. In order to allow manual operations both hands are required so devices like glasses are preferred.

5.2.2.2 *Role of SatisFactory for selected operations at an automotive manufacturing shop floor*

SatisFactory proposes a framework for creating a collaborative and augmented-reality ecosystem for increasing safety, training and improving working experience. In the light of this, the aim will be to develop a set of tools that will be able to “record” all the steps executed by an operator during the assembly operations and translate them into an animated sequence of steps represented using augmented reality. The main Business Scenario for demonstration will be to evaluate the capability of the SatisFactory framework to “record” all the steps executed by an operator during the assembly operations and translate them into an animated sequence of steps represented using augmented reality and gamification aware concept for increasing workers satisfaction along with appealing user interfaces (attractiveness), during e.g. training activities.

The idea is to have a set of tools for recording the operation activities, recognizing objects, components, tools and movements in scene and replaying them in augmented or virtual reality environment to support ordinary or emergency activities in production or maintenance environment. In addition to the training aspect, another very important benefit of the implementation will be the possibility to perform a real-time quality control on the assembly operation and verify the correct execution of the task in terms of sequence of steps and correct positioning of parts and components to avoid mistakes and dangerous operations. This kind of tools can contribute in lowering the stress level in the workers involved in the assembly operations, usually concerned about the human errors.

The role of the SatisFactory platform with respect to the remote support activities that take place at BSC-2.1 is to provide the necessary tools to allow engineers sitting in the office to “see through remote cameras” what happens in the shop-floor and provide to the maintenance staff contextual information and documents on the faults occurred in order to fix it promptly reducing the MTTR (Mean Time To Restore) of the production systems. The activities within this Application Scenario could also be used for remote training applications.

5.2.3 *Progress on the Business Scenarios in automotive manufacturing shop floor*

According to the COMAU use-case development Gantt, the activities performed in the current period focus mainly the engineering and implementation of the intermediate prototype. This includes the overall application definition as well as the hardware and software development. In the following picture the updated roadmap is presented.

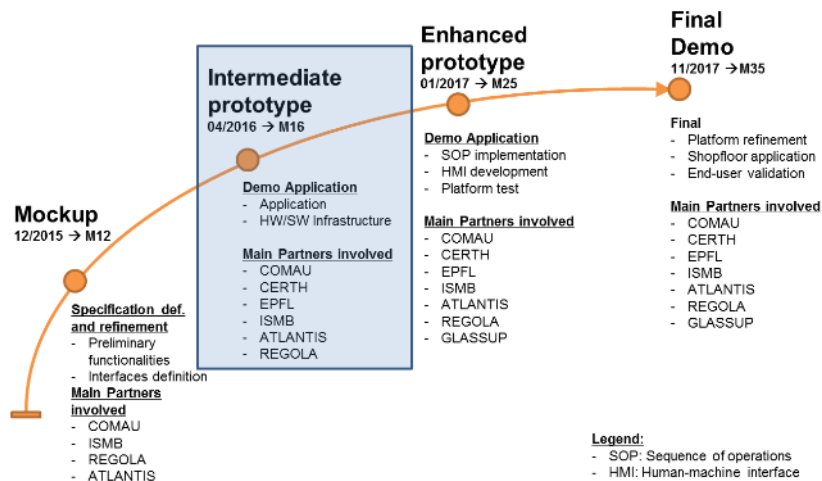


Figure 29: Implementation Roadmap

Activities performed in COMAU business scenarios so far consist in two steps:

- first step, that is the prioritization of the scenarios presented in previous sections of this document, in order to demonstrate and exploit the preliminary SatisFactory achievements in a concrete real manufacturing environment. In this sense the BSC-1.1 that is related to the “*manual assembly operations with focus on Robot Wrist assembly*”, has been identified as most representative. Following picture shows in red the product of this specific assembly operation.

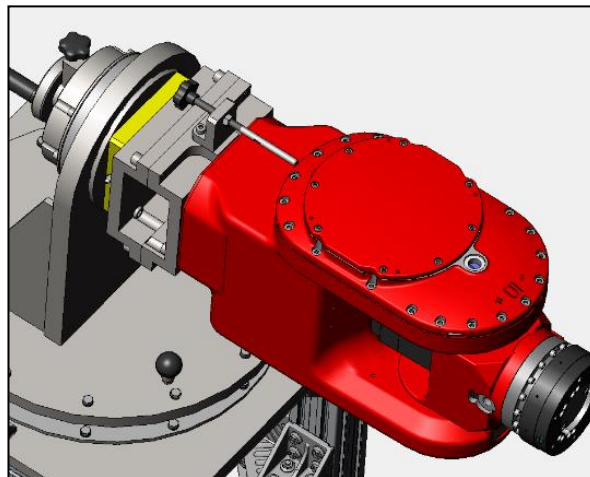


Figure 30: Robot wrist

- second step, that includes (i) the workplace reorganization and preparation of the area for new tools and devices such as digital measurement tools, the fixed/mobile interfaces (PC/tablet, etc.) and cameras for A.R. Application; (ii) Feasibility study with different concepts and implementation hypothesis; (iii) Digital measurements tools acquisition and tests for integration.

The main idea is to develop a digital innovative workplace that guides the operator in the manufacturing process. To this aim the work-bench should include new devices such as screw storage bins including the “pick-to-light” to show the operator the correct screw to be used in a specific step, terminals guiding the operator with interactive assembly procedures, cameras to acquire real-time pictures needed in the augmented reality platform, RFID sensors to recognize the correct tool usage and digital tools (or instruments) in order to digitally acquire the measurements performed.

Moreover the operator should be equipped with a “sensorized jacket” that allows a real-time monitoring of ergonomics and safety parameters, which are fundamental for a workplace improvement. Following picture shows how all these concepts will fit together.

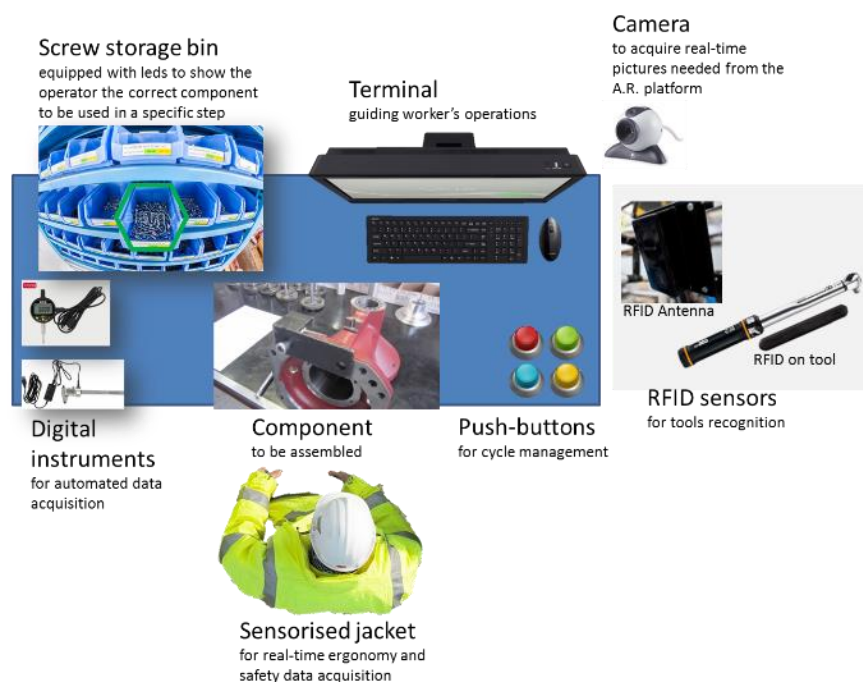


Figure 31: Innovative workplace concept

The workplace reorganization consists in a complete redistribution of the everything is composing the area in order to keep the workplace clean, more efficient, reduce un-useful steps and to create the space required for cameras and computer/tablet installation as well as the space for the new tools and measurement instruments. Once the workplace has been prepared for the new equipment a feasibility study has been performed. The result is shown in the following pictures and 3 implementation hypotheses have been formulated:

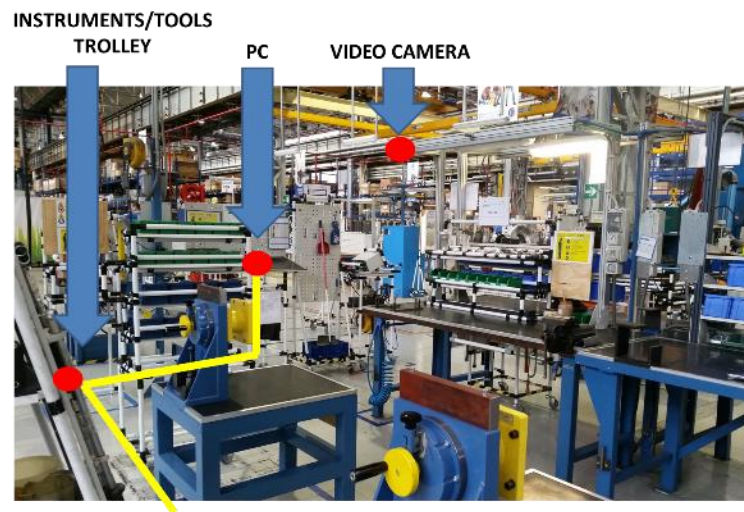


Figure 32: Innovative workplace 1st implementation hypothesis

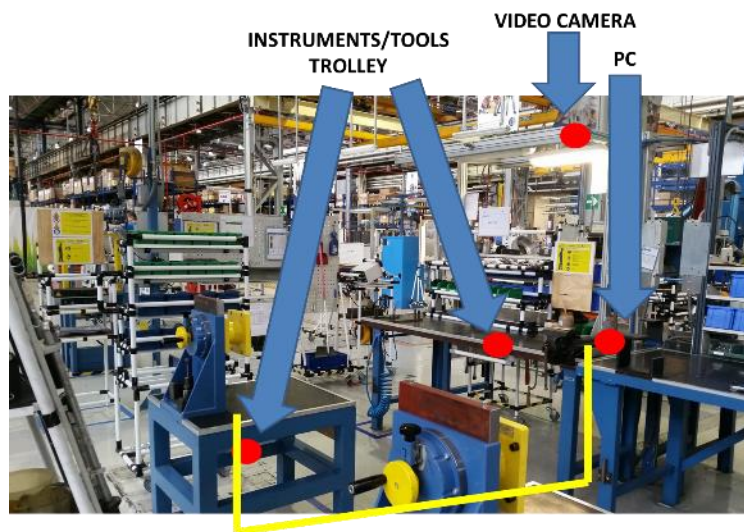


Figure 33: Innovative workplace 2nd implementation hypothesis

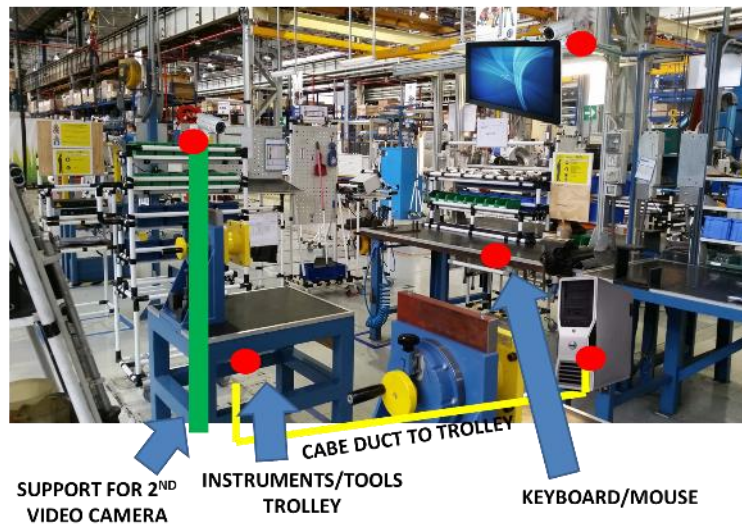


Figure 34: Innovative workplace 3rd implementation hypothesis

The digital instruments acquisition has been done analysing the actual tools used in the shop-floor and performing a market research of devices able to provide a real-time measurement through a USB cable.

The acquired instruments are:

- Mitutoyo caliper, 0 to 150 mm, model M50016130



Figure 35: Digital caliper

- Mitutoyo micrometer, for external measurements 0 to 1", model M29323130



Figure 36: Digital micrometer

- Mitutoyo Digital dial 0,01 C.12,5, model M543400B



Figure 37: Digital dial

- Sauter Digital Force Gauge (Dynamometer) 20kg/200N 0,1N Traction/Compression, model GDD200020



Figure 38: Digital force gauge

- Facom Torque wrench 10-200 NM 14X18 1/2", model FE.306A200S



Figure 39: Digital torque wrench

While all Mitutoyo tools are plug and play (this means that they are seen by the computer as Human Input Devices - HID), the Sauter Force Gauge comes out with a serial port that allows the connection to a printer, but it does not provide a real-time measurement. Different is the Torque wrench that allows acquiring several measurements that can be downloaded with a specific software in the computer in a csv file. This will require specific Hardware and Software developments to implement HID functionalities also in these devices.

Since the BSC definition, the development activities have been carried out also in the GUI definition and implementation. Following picture presents a preliminary version of the interface that will be described more in detail in technical deliverables.

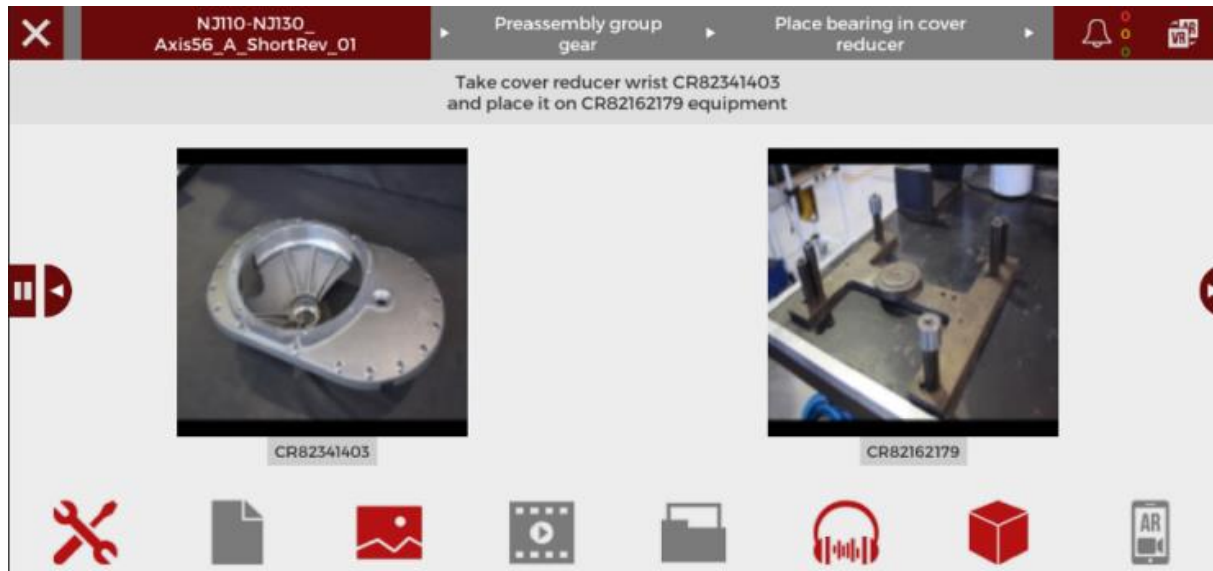


Figure 40: Augmented reality platform interface

The activities have been performed by COMAU in collaboration with Regola for the workplace reorganization, interface definition and Augmented Reality application and ISMB for the jacket sensors selection as well as cameras selection, that will also be applied and tested for gestures and protection devices (helmet, jacket, gloves, etc.) wearing in upcoming implementation steps.

5.3 BUSINESS SCENARIOS AT BATTERIES MANUFACTURING SHOP FLOOR (SUNLIGHT)

The factory chosen from the energy sector (SUNLIGHT) is producing batteries in a semi-automatic way. SUNLIGHT's currently has four production lines and seven assembly lines in operation for the manufacturing of various types of batteries used in a wide range of applications. For the proposed project two of the assembly lines will be involved where various manual and automatic actions take place that transform the raw materials and components to a fully functional ready to use product. The manufacturing process of a lead-acid cell consists of various stages: casting, pasting, filling, curing, formation, assembly and packaging stage. SatisFactory is expected to contribute towards a novel and efficient solution that will take into consideration the available data on the shop floor and transform them into easy to understand information for employees and thus clarify the flow of battery lines. For SUNLIGHT's shop floor two Business Scenarios are identified to be used during SatisFactory project in order to show the applicability of the SatisFactory platform to a batch production shop floor.

5.3.1 BSC-3 Knowledge enabled support of systems and workforce for semi-automated battery assembly lines (SUNLIGHT)

The third Business Scenario of the project is related with the handling of planned actions that are the outcome of cumulative knowledge as recorded by the maintenance activities that support the production lines at SUNLIGHT's shop floor. These maintenance activities deal with the analysis and the restore of a malfunction in the production machinery. The malfunction could be electrical or mechanical. Every day the maintenance team is facing several incidents concerning machinery malfunctions. The main scope of this action is to increase the satisfaction of the technical team in their everyday business. In addition, by using an online communication and logging system the maintenance department will operate in an easier and efficient manner. The knowledge enabled support of the systems will be demonstrated by one Application Scenario:

- BSC-3.1 Preventive and corrective maintenance management system



Figure 41 Maintenance procedure at SUNLIGHT

5.3.1.1 BSC-3.1 Preventive and corrective maintenance management system

Table 35 SUNLIGHT Application Scenario 1 characteristics

Application Scenario #	BSC-3.1
Application Scenario Name	Preventive and corrective maintenance management system
Version/Author	V1 / SUNLIGHT (SP)
Goal	Improve the working environment in the technical department
Type	Preventive actions – Predetermined or Condition-Based Corrective actions - Deferred or Immediate
Challenges	The challenge is to provide in each assembly stage all the necessary technical information to the actors in a 'smart' way. The challenge is to organize the maintenance works, provide to the technicians all the necessary technical information to perform their job and record all the critical data for further analysis. These factors will increase the technician work satisfaction and will maximize the performance of the maintenance department.

Involved Actors	Technicians, workers, foreman
Pre-conditions	Not Applicable for preventive actions. Existing of fault for corrective actions.
Post-conditions (Minimal Guarantees, Success Guarantees)	Minimal Guarantees: Perform successfully the maintenance works Success Guarantees: Organize the maintenance works effectively and increase satisfaction
Realization Concept	<p>The system should provide to the technicians online information about the preventive maintenance work schedule and/or the corrective maintenance work schedule when a malfunction happens and there is a need for re-organise the work schedule. The technicians will be also informed about the tasks that are assigned to each person. Additional information, such as working instructions, necessary spare parts and the progress of each work, will be also available to the technicians. The information will be displayed in a tablet or smart phone. The technicians and the maintenance manager will be able to chat and receive additional instructions or information when it is necessary. Any unexpected incident such as a technical malfunction will be assigned to a technician providing him a priority grade that will inform him how quick he must act. The system should be also integrated with the gamification platform, providing input to the Maintenance Game.</p> <p>The maintenance manager will have all the information in his tablet or laptop and he will be able to support the technicians. He will check the progress of the works and advise them accordingly.</p>
Brief Description / Main flow	<p>The application scenario can be described by the following steps:</p> <ul style="list-style-type: none"> • Definition of the performed maintenance • Action planning • Work scheduling • Work assignment • Work execution • Work completion • Production of Reports
Frequency of use	Preventive: According to the manufacturer or according to the Preventive Maintenance Schedule. Corrective: Whenever a malfunction incident occurred
Extensions or Alternate scenarios	Not Applicable
Trigger	Preventive Maintenance Schedule or a Malfunction incident
Duration	Not Applicable
Stakeholders and Interests	Maintenance manager, Production planner, Production plant manager
Special requirements	Safety: All actors involved in the application scenario MUST keep to the safety requirements and the instructions given by the safety manager

5.3.2 BSC-4 Monitoring and learning activities at battery production lines (SUNLIGHT)

The fourth Business Scenario of the project deals with the monitoring and learning activities at the involved battery production lines. In order to demonstrate the importance of the monitoring and training activities three Application Scenarios will be developed that cover a multitude of operations that take place at the shop floor with various group of workers with different responsibilities. The three Application Scenarios involved at the shop floor of SUNLIGHT related to daily operations and training activities are:

- BSC-4.1 Motive power battery assembly line
- BSC-4.2 Monitoring of the Cell Temperature during Jar formation and data collection
- BSC-4.3 Training platform for production process motive power batteries assembly line

5.3.2.1 BSC-4.1 Motive power battery assembly line

Application Scenario BSC-4.1 describes the motive power battery assembly line. The batteries that are produced in this department are intended for use in electrical vehicles, mostly for forklifts. The assembly line is divided in six stages. In the first stage, the battery cells are placed in the metallic box. There are several types of batteries. Each type requires a particular placing order of the battery cells. In the second stage, battery cells are connected together creating a battery string. In the next stage, battery cells are checked whether they need additional electrolyte filling or not and sealed with regular or water filling plugs. In the next two stages, the terminal plugs and the labels are installed and a quality check is being performed. Finally the batteries are packed and forwarded to the warehouse for dispatch.



Figure 42 Battery assembly procedure at SUNLIGHT

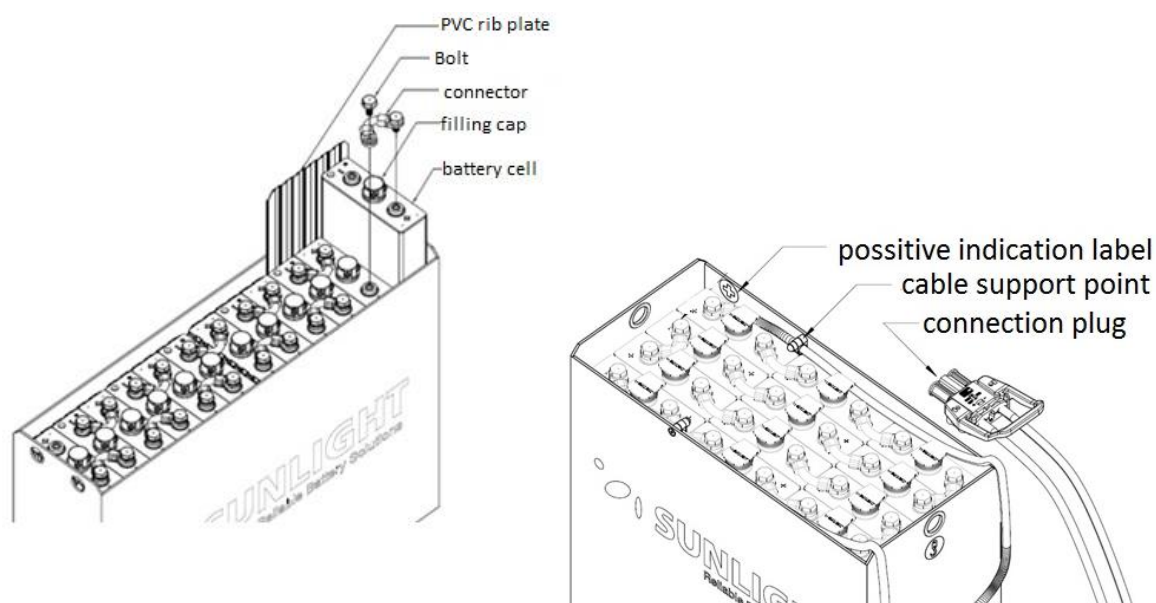


Figure 43 Battery assembly technical drawings

Table 36 SUNLIGHT Application Scenario 2 characteristics

Application Scenario #	BSC- 4.1
Application Scenario Name	Motive power battery assembly line
Version/Author	v0.3 / SUNLIGHT (SP)
Goal	Improve the working environment in motive power batteries assembly line
Type	Preventive actions - Predetermined
Challenges	The challenge is to provide in each assembly stage all the necessary technical information to the actors in a 'smart' way. Reduce confusion and misinterpretation of request job Identification of the respective physical world objects that are mentioned in the descriptions. Create a better bond of workers with the product
Involved Actors	Production supervisor, Workers, Foreman
Pre-conditions	Not Applicable
Post-conditions (Minimal Guarantees, Success Guarantees)	Minimal Guarantees: Assembly motive power batteries Success Guarantees: Assembly motive power batteries retrieving all the necessary technical information from an information system through a context aware tablet or computer. Workers have knowledge what the product is used for and are proud of it.

Realization Concept	The system should provide information about the motive power battery assembly line such as mechanical drawings, connections diagrams, assembly instructions, inspection instructions, packing instructions. All this information would be easy accessible from the actors and would be displayed in tablets or wall screens located in the shop floor. The system will display the list of Work Orders that will be executed in each working day and provide the relevant information on the screens. The system should be able to provide additional information to the supervisor such as incidents detection or workers localization. This information should be transferred also to other components of the system in order to automatically trigger procedures or actions.
Brief Description / Main flow	The motive battery assembly line follows the following procedure: <ul style="list-style-type: none"> • Definition of the Production Order • Provision of the required drawings or working instructions • Battery assembly execution • Quality control • Labeling and packing • Customer order completion
Frequency of use	Not Applicable
Extensions or Alternate scenarios	The physical world articles are already in the correct order so that there is no need for the worker to match from screen to physical world.
Trigger	Work order issued by the production planner or supervisor
Duration	3 hours
Stakeholders and Interests	Production manager, Production planner
Special requirements	Safety: All actors involved in the Application Scenario MUST keep to the safety requirements and the instructions given by the safety manager

5.3.2.2 BSC-4.2 Monitoring of the Cell Temperature during Jar formation and data collection

Application Scenario BSC-4.2 describes the process of monitoring the battery cell temperature measurement in the jar formation. There are eleven jar formation modules which are installed in two rooms. Each room is approximately 500 mm². The Cell Temperature during the formation process is a critical parameter which must be continuously monitored. Measurements are taken manually by applying a sampling rate of one measurement per hour. There is one person per shift who is in charge to scan each battery cell with the thermal camera in order to check if the temperature is below the limit. This person who is walking around the jar modules in a total area of 1000 mm², scanning one by one the battery cell in formation process. The main scope of SatisFactory is to make this procedure more automated for the workers and save man hours and effort. In addition the temperature monitoring will be continuous and more reliable.



Figure 44 SUNLIGHT Jar formation units



Figure 45 SUNLIGHT manual temperature monitoring procedure

Table 37 SUNLIGHT Application Scenario 3 characteristics

Application Scenario #	BSC-4.2
Application Scenario Name	Monitoring of the Cell Temperature during Jar formation and data collection
Version/Author	V1.0 / SUNLIGHT (SP)
Goal	Remote monitoring of the cell temperature continuously during the Jar formation, data collection and analysis
Type	Preventive action - Continuous
Challenges	The challenge is to identify a cell failure during the Jar formation.
Involved Actors	Production supervisor, Workers
Pre-conditions	Not Applicable
Post-conditions (Minimal Guarantees, Success Guarantees)	<p>Minimal Guarantees: Identify the overheated battery cells during the Jar formation and remote monitoring of Jar platforms.</p> <p>Success Guarantees: Identify any unusual temperature increment as soon as possible and continuously monitor the Jar platforms.</p>
Realization Concept	A thermal supervision system that will be installed, will continuously supervise the battery cells temperature during the formation process. It will be able to provide an alarm in case that the temperature will be out of limits. In case that any of the battery cells will overheat, the system will detect it immediately. This information will be transferred to the relevant Satisfactory component which will inform the production supervisor and assign the corrective action to the relevant person. The actors will not detect the overheating incidents manually anymore. This will increase the sense of safety level in the shop floor and it will allow for faster and more effective actions.
Brief Description / Main flow	<p>Battery cell temperature monitor during the jar formation can be described by the following:</p> <ul style="list-style-type: none"> • Identification of the condition-based preventive action • Alarm recognition

	<ul style="list-style-type: none"> • Alarm acknowledgment • Work assignment • Work execution • Work completion • Production of Reports
Frequency of use	Not Applicable
Extensions or Alternate scenarios	Not Applicable
Trigger	Battery cell overheating
Duration	Not Applicable
Stakeholders and Interests	Foreman, Production supervisor
Special requirements	Safety: All actors involved in the application scenario MUST keep to the safety requirements and the instructions given by the safety manager.

5.3.2.3 BSC-4.3 Training platform for production process motive power batteries assembly line

Application Scenario BSC-4.3 refers to the need of a training platform which will help the trainees to understand how to perform their job safely and more efficient. This procedure includes two parts. The first one concerns the theoretical approach that will provide to the trainees the background of each particular process. In the second part the trainees will receive on work training which will incorporate also AR devices making the process more attractive to the trainees. The platform will include also a trainee evaluation questionnaire which will evaluate whether the trainee has been trained sufficient or not.

Table 38 SUNLIGHT Application Scenario 4 characteristics

Application Scenario #	BSC-4.3
Application Scenario Name	Training platform for production process motive power batteries assembly line
Version/Author	V1.0 / SUNLIGHT (SP)
Goal	Develop a training platform to demonstrate production processes to the trainees. Make sure the training is understood by trainees
Type	Preventive action - Predetermined
Challenges	The challenge is ensure that the trainees will receive all the necessary information to perform the job correct and safely. Make sure the training is reflected and repeated

Involved Actors	Foreman, Workers
Pre-conditions	Not Applicable
Post-conditions (Minimal Guarantees, Success Guarantees)	Minimal Guarantees: Train the personnel in several production processes Success Guarantees: Train the personnel by using an augmented reality platform and devices. The personnel has reflected and repeated the training's content
Realization Concept	A training platform that will incorporate augmented reality devices such as glasses and context aware tablet or smart phone. The workers will receive the necessary training information, faster, more reliable and in a more attractive and interactive way. After the completion of the training, the workers will be asked to fill up a questionnaire in order to verify that they have consolidated the training theory.
Brief Description / Main flow	<ul style="list-style-type: none"> • Identification of training needs • Determination of the training field • Implementation of the training • Evaluation of the training • Training in the workplace • Provision of the training information
Frequency of use	Not Applicable
Extensions or Alternate scenarios	Not Applicable
Trigger	Training demand
Duration	Not Applicable
Stakeholders and Interests	Foreman
Special requirements	Safety: All actors involved in the application scenario MUST keep to the safety requirements and the instructions given by the safety manager.

5.3.2.4 Role of SatisFactory for selected operations at a batteries manufacturing shop floor

As the production lines need to be used in a flexible way to produce different sizes of batteries, the role of SatisFactory platform is to deliver a set of easy to use tools that would help the everyday activities of the workers, both the experienced and the novice ones. Therefore the workers and mostly supervisors by using SatisFactory's AR enabled devices will be able to observe the changes in the production line by pointing to temporary locations of goods in the shop floor. By identifying the locations it will be able to reorganize the production line in an optimal way and communicate this with workers eliminating the need for additional retraining on procedures. The workers on the other hand would consult their own personal devices on those reorganizations. In this context, SatisFactory envisions the adaptation of the specific traditional production lines with several innovative assistive ways, in which the possible increase in production or/and satisfaction of the workers would be

reported and demonstrated along with lessons learned for their further take-up to the respective market.

SatisFactory AR functionalities will provide to the workers an overview of their action and activities during the day, as well as real-time information about changes regarding their work such as the components to be used, or modification to the amount of the cells that need to be produced. Thus, the workers will intuitively understand the status and the various conditions of the process equipment and respond accordingly upon demand. SatisFactory is also expected to enable the automated logging of the status of the cells and also provide instant information about the suggested outcome of the quality check. In case of a problem the operations supervisor will be informed in order to proceed to corrective actions.

SatisFactory training platform is expected to contribute greatly in the SUNLIGHT production lines, allowing the fast training of new employees of the adaptation of the workforce to new technologies. As workers periodically work at a different production line or machine it is important to perform short term training as a reminder of the needed procedures to be performed without disrupting the workflow of employees. Figure 46 shows the roadmap for Business Scenarios development and deployment at the shop floor.

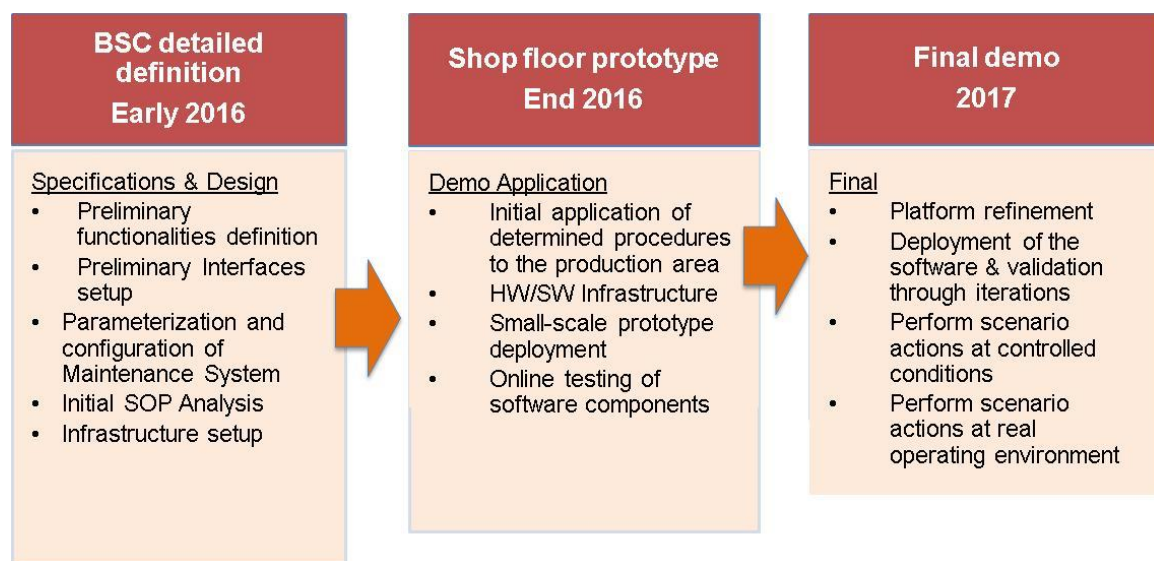


Figure 46 SUNLIGHT roadmap for Business Scenarios

5.4 BUSINESS SCENARIOS AT CHEMICAL PROCESSES SHOP FLOOR (CERTH)

The following business scenarios have come up from the daily needs of a semi industrial environment. This is the shop floor of CERTH/CPERI. There are several pilot plants with different procedures and functions within the shop floor. These pilot plants consist of many complicated components performing several procedures. Every day, many workers of CERTH/CPERI perform several actions at the shop floor. One of the goals of SatisFactory is to assist workers with their daily actions improving efficiency and fast response at unplanned events, online sharing of knowledge,

improvement of the planned maintenance actions by acquiring flow diagrams and electrical schematics and with other similar actions.

5.4.1 BSC-5 Online supervision of the operation and workforce resources of pilot plants for chemical processes (CERTH)

There are three Application Scenarios involved that cover a subset of activities that are performed at daily basis at the shop floor of CERTH/CPERI:

- BSC-5.1 - Repair or restore an electromechanical malfunction
- BSC-5.2 - Startup procedures for pilot plants
- BSC-5.3 - Reconfiguration of process flow and actions for flexible redesign of production procedures

5.4.1.1 BSC-5.1 - Repair or restore an electromechanical malfunction

Application Scenario BSC-5.1 is about corrective actions that need immediate attention. Various malfunctions may occur during the normal operation of a pilot plant. Some of them can be treated after the current operation is completed while others need immediate attention in order for the pilot plant to continue the scheduled actions. An electromechanical malfunction may need immediate care to avoid safety issues as well. Technicians must be very careful when they are working at an operating pilot plant. Their actions must be accurate in order to avoid any further malfunctions or accidents. The components of SatisFactory that are applied in this Business Scenario provide the necessary assistance to the involved actors in order to make their work easier and safer. This has positive impact on the needed time to finish the sequence of actions and reduces the possibility of human mistakes.

When a complex electromechanical system fails, the troubleshooting procedure required is often complex and tedious. No standard methods currently exist to optimize the sequence of steps in the troubleshooting process. The ad hoc methods generally followed are less than optimal methods and can result in high maintenance costs, non-optimal usage of resources, delays, mental fatigue and increase of work-related stress. The purpose of this application scenario is to organise all current applied methods and solutions regarding this kind of malfunctions and assist technicians while they are working.

Various novel technologies have been applied through the involved SatisFactory components trying to increase the satisfaction of the workers and their effectiveness. The co-operation of existing automation systems with the SatisFactory components that has been developed is the key for the success of this application scenario.

The live data of the status of the pilot plant are inputs to complicated algorithms that are responsible to locate the malfunctions and trigger the scenario. After that, the SatisFactory platform will manage the procedure and perform the necessary actions. It informs all the involved personnel and the visualization toolkit displays the required drawings and schematics and the needed tools and spare parts.

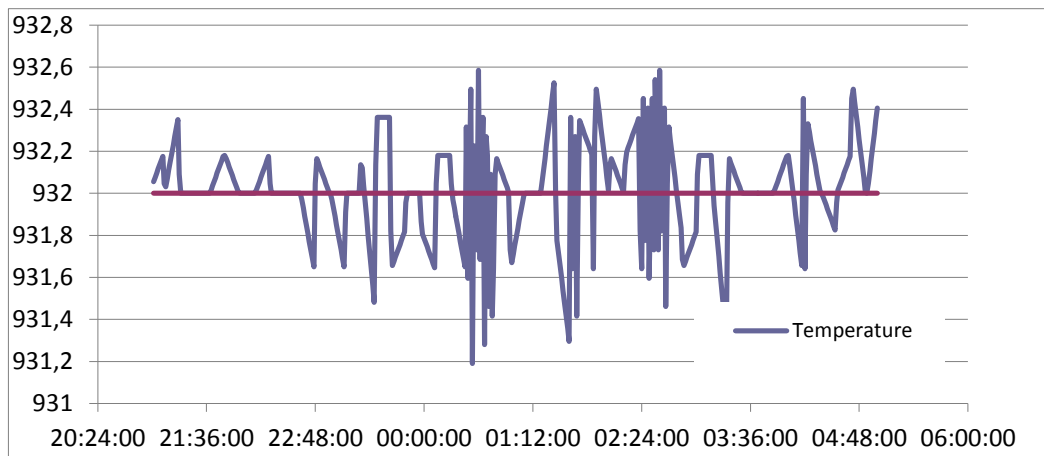


Figure 47 An example of live data of the status of the pilot plant

This function could be a great assistance to a non-experienced technician because he/she will be able to check all the actions he/she is willing to make through the SatisFactory platform. In this way, the confidence of the employees is higher as well as their safety because any incorrect actions will be avoided.

The materials that will be involved in this application scenario are:

- Fuse
- Solid State Relay
- Terminals
- Resistor
- Multimeter
- Wires

At the next picture, a part of a reactor with a heating resistance is displayed and the complexity of the system is very clear. Therefore, all the actions of the technicians must be accurate in order to have the optimal result avoiding any accidents or further damages to the pilot plant.



Figure 48 Part of a reactor, including a heating resistance at CERTH/CPERI

All the necessary actions in order to repair this kind of malfunctions and continue the normal operation of a pilot plant at the shop floor of CERTH/CPERI are being described at the next table.

Table 39 CErTH Application Scenario 1 characteristics

Application Scenario #	BSC-5.1
Application Scenario Name	Repair or restore Electromechanical malfunction
Version/Author	V1 / CErTH/CPERI (CZ)
Goal	Perform work to repair or replace a faulty or degraded equipment
Type	Corrective actions - Immediate
Challenges	The challenge is to reduce the time to respond to a malfunction and to automatically provide appropriate information for the evaluation of the fault and the necessary actions to be performed or executed by the involved actors.
Involved Actors	Maintenance team (manager, technicians: electrical, process, control) Process operators / Process manager
Pre-conditions	Existing of faulty or degraded equipment
Post-conditions (Minimal Guarantees, Success Guarantees)	Minimal Guarantees: Replacement of faulty or degraded equipment Success Guarantees: Replacement of faulty equipment with minimum or no downtime of the operation of the Pilot Plant and not losing any data of the ongoing experiment continuing as if the problem did not occurred at all
Realization Concept	The system should provide information about the process conditions and information about the specific malfunction to support the actor that will repair or replace the component at the process unit. The appropriate information about the electrical components and the respective schematics and drawings should be automatically determined and presented upon request to the maintenance team using the respective table with the intuitive HMIs. The system has been also integrated with the gamification platform, providing input to the Maintenance Game. Thus, when a worker fulfils the task of the replacement, points will be added to his account at the gamification platform.
Brief Description / Main flow	<p>Task collection and Definition</p> <p>Identification of the malfunction either from the process operator or from the automation (SCADA) system. Examine the kind of the malfunction and define between corrective or preventing maintenance. Afterwards contact the floor manager or the process supervisor, inform them about the identified problem and proceed to the planning of the actions.</p> <p>Work Planning – Design of the work</p> <p>Prioritize the listed components based on importance or criticality to operation, process, or mission and request for a Work Order. Determine the type and number of maintenance activities required using equipment history, engineering judgment and process conditions. Study the procedure documents for the specific case as well as the feedback documents for similar previously occurred malfunctions. Assign priorities to separate works and create planning sheet. Study of factory specific documentation and internal maintenance audits in order to decide the appropriate actions for the malfunction. Cross-reference the spare parts list and make estimation of the necessary resources.</p> <p>Work Scheduling</p>

	<p>After being sure to have the appropriate tools, spare parts and manpower resources and according to the procedures of the planning sheet, reserve the time slot to perform immediately each maintenance activity. Assign the resources in order to avoid misunderstandings and delays. After the assignment the scheduling sheet is created.</p> <p>Release – Assignment of the Work Order</p> <p>Having in mind the Scheduling sheet create a work order release and assign the available resources to the work orders backlog.</p> <p>Execution - Carry Out the Work</p> <p>All information from previous steps must be complete and available as well as the necessary tools and manpower. Works are carried out according to the W.O. During the procedure, information on the workflow and completion is given if necessary to the process manager or else. Create registers of the used items in order to update the remaining stock levels.</p> <p>Closure of the work order</p> <p>Perform a cross-check between the current status and behaviour of the replaced part with the optimum documented behaviour. Verify that the performed actions had good effect on the problem and also verify that all safety measures are being followed. Record the working hours needed to solve the problem. The system, automatically adds points to the account of the specific worker who carried out the job, at the gamification platform.</p> <p>Production of Reports</p> <p>Compare the W.O. list with the works been successfully done and fulfil history records with the maintenance operations. Inform the floor manager and the process supervisor about the results and if any further actions are required. Update the respective online (electronic) log book to be used as a future reference case. Create reports according to the history records and the performed procedures. Collect historical data from the database and try to find the reason of the malfunction. Make a list of all activities in which resources were used and a list with the above resources. Analyse the created reports from the previous step and create feedback documents. Make proposals for performing the procedures or handling of the equipment better that can potentially improve the results of the workflow either on manpower use, cost or on the final operation outcome. Analyse equipment failure modes and impacts on components and systems.</p>
Frequency of use	Not Applicable
Extensions or Alternate scenarios	There is no stock of the faulty equipment at the store
Trigger	Alarm indicated from the SCADA system or recognized from the process operator
Duration	3 hours
Stakeholders and Interests	Process supervisor, Maintenance supervisor
Special requirements	Safety: All actors involved in the application scenario MUST keep to the safety requirements and the instructions given by the safety manager

5.4.1.2 BSC-5.2 - Startup procedures for pilot plants

Application Scenario BSC-5.2 is about the critical start-up step of operating hydroprocessing pilot plants and involves the loading of the feed tank, as the first step of the overall experimental plan, which needs to be carefully performed to allow the optimal feedstock introduction in the downstream catalytic system.

The actions that need to be performed are specific and a Standard Operating Procedures (SOP) document can cover all our needs about this scenario. Of course, the SOPs are not being represented with a simple document but with AR tools and components that have been developed for the project. Along with the other involved components of SatisFactory, the assistance that the involved actor will have, will give him all the necessary information that is needed to fulfill the required actions.

The Standard Operating Procedures are often updated to insure of obedience to the realization conditions and the working practice. A minimum review list of 3 years is recommended. Changes of the Standard Operating Procedures are activated generally when a process or procedure changes. These changes should be led by the internal site controlling procedure. The activity list of such changes should update the coherent standard operating procedures. Standard operating procedure should be in place for all the sub-systems of the pilot plant plus the specific operational activities that the operators perform.

The steps that are part of the SOPs have been filtered very carefully in order not to be too complicated or to have any ambiguous meanings. Both experienced and novel operators are being assisted from these procedures but the most crucial objective is to avoid any errors at the procedure that will have bad results (safety or operational issues). Prior to the development of a SOP for the hydroprocessing pilot plant we have taken into consideration all the necessary information about the involved materials because of the fact that there are chemicals involved at the procedure and there is danger of contamination. This information is:

- Type, quantity, and nature of the chemical used. Note that the Safety Data Sheet (SDS) lists important information regarding potential hazards that will need to be considered, such as toxicity, flammability, reactivity, warning properties, and symptoms of exposure.
- Location of use, including fume hood or other containment devices. Include specifically-designated work area for "particularly hazardous substances."
- Process details.
- Available safety equipment, including personal protective equipment.
- Waste collection, storage, and disposal requirements.
- Decontamination procedures.

All the above have of course been considered before the creation of the SOP for the hydroprocessing pilot plant at CPERI. All involved actors, mostly process operators, are taking special training regarding chemical dangers and safety. This application scenario enhances their sense of safety when they are working at the shop floor.

The proper feed tank loading is the result of starting the recycling pump and systematically heating the feed lines according to the specific feedstock quality characteristics and experimental run objectives set the process supervisor and implementing the loading strategy by the process technician. It is also important that feed tank loading follows the proper maintenance of the hydroprocessing plant, to allow technical problems during the future experimental run. This Application Scenario has as a goal to make sure that the proper steps will be followed even from workers with small experience.



Figure 49 The loaded feed tank of a CETH/CPERI pilot plant

The challenge is to create a standard procedure for starting up a pilot plant in order first to reduce startup time and second to avoid errors during the startup procedures increasing the safety and reducing stress. The final goal is to Startup the pilot plant with no errors or conflicts and with the least usage of recourses (time consumed, actors involved, materials and tools needed)

Table 40 CETH Application Scenario 2 characteristics

Application Scenario #	BSC-5.2
Application Scenario Name	Startup procedures for pilot plants
Version/Author	V1.0/ CETH/CPERI (CZ)
Goals	Normal startup of a pilot plant
Type	Scheduled actions
Challenges	The challenge is to create a standard procedure for starting up a pilot plant in order first to reduce startup time and second to avoid errors during the startup procedures increasing the safety and reducing stress.

Involved Actors	Process operators, Process supervisor, Process technician, Maintenance supervisor
Pre-conditions	All parts of the pilot plant to be ready for startup. The process operators must be familiar with the involved technological equipment.
Post-conditions (Success Guarantees, Failure end conditions)	Success Guarantees: Normally startup of the pilot plant Failure end conditions: Pilot plant didn't startup or started with errors
Realization Concept	The startup procedures of the pilot plants must be documented and inserted into the system (written guides, diagrams, photos, videos). The involved actors are guided through the technological components to perform the appropriate actions in order to achieve the optimal startup
Brief Description / Main flow	<p>Task collection and Definition Collection of the user's manuals of the pilot plants and any other document related with the startup procedures (e.g. safety instructions). Examine along with the process operators the actual procedures (may differ from the written), the time needed for a normal startup and possible problems.</p> <p>Work Planning – Design of the work After the collection of the necessary information, categorize the needed actions, create sets of actions for each category and record the proper methods of accomplish them.</p> <p>Work Scheduling After being sure to have the appropriate tools, spare parts and manpower resources and according to the procedures of the planning sheet, reserve the time slot to perform the startup.</p> <p>Release – Assignment of the Work Order Having in mind the Scheduling sheet create a work order release and assign the available resources to the work orders backlog.</p> <p>Execution - Carry Out the Work All information from previous steps must be complete and available as well as the technological equipment and manpower. The steps of the procedures are carried out as written and shown on the tablets</p> <p>Closure of the work order Check whether the startup of the pilot plant has completed successfully and the normal operation is ongoing, according to the manual of the specific pilot plant.</p> <p>Production of Reports Compare the W.O. list with the works been successfully done and fulfil history records of the pilot plant. Inform the process supervisor and the process operators about the results and the next steps. Make a list of all activities in which resources were used and a list with the above resources. Make proposals for performing the procedures or handling of the equipment better that can potentially improve the results of the workflow either on manpower use, downtime, cost or on the final operation outcome.</p>
Frequency of use	Every time a pilot plant startup
Extensions or Alternate scenarios	The startup procedure has interrupted by an external factor (e.g. power failure)

Trigger	Process operator or process supervisor request to startup up a pilot plant
Duration	The duration varies between different pilot plants
Stakeholders and Interests	Floor manager, maintenance manager
Special requirements	Performance: The faster the procedure completes the better User interface: The instructions must be clear and easy to follow from the involved actors

5.4.1.3 BSC-5.3 - Reconfiguration of process flow and actions for flexible redesign of production procedures

BSC-5.3 of CERTH refers to the need to alter the operation of a pilot plant. A set of pre-defined jobs, a Solution Package, will change the operation of the pilot plant from a point A to a point B. Solution Package is a pre-defined set of works which can include materials, tools, and labour required to complete a specific job. In order to follow a specific and approved method for creating a solution package for this Business Scenario we chose to follow the MIMOSA OSA-EAI standard.

The MIMOSA OSA-EAI specification provides:

- An information exchange standard to allow sharing asset registry, condition, maintenance and reliability information between enterprise systems and
- A relational database model to allow storage of the same asset information.

The OSA-EAI uses a layered architecture to allow individual components to be used independently to satisfy functional requirements. The OSA-EAI offers advantages for maintenance and reliability users as well as technology developers and suppliers. For users, the adoption of MIMOSA OSA-EAI facilitates the integration of asset management information, provides a freedom to choose from a broader selection of software applications, and saves money by reducing integration and software maintenance costs. For technology suppliers, the adoption of MIMOSA OSA-EAI stimulates and broadens the market, allows concentration of resources on core high-value activity rather than low value platform and custom interface requirements, and provides an overall reduction in development costs. Taken as a whole, maintenance and reliability information is complex. A Collaborative Maintenance network must provide for the open exchange of equipment asset related information between condition assessment, logistic, and maintenance information systems. The condition assessment sector must include the specialized data required by vibration, oil analysis, infrared thermography, motor circuit evaluation, and many other technologies.

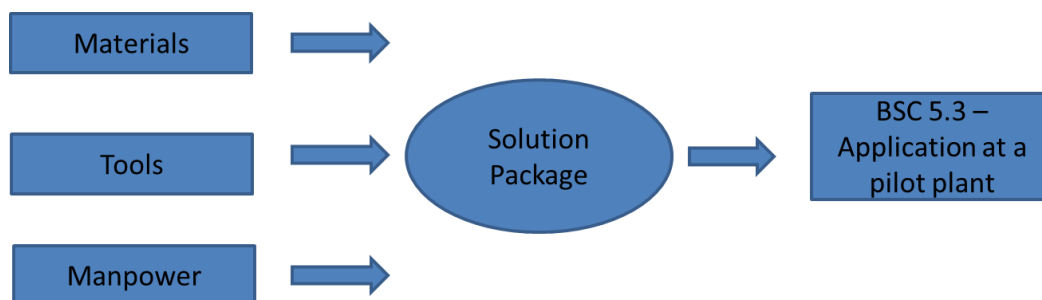


Figure 50 Creating a solution package

OSA-EAI V3.2 will support Solution Package Steps and specifying the exact required resources of materials, tools, documents, and labour. Since this set of works is defined and become input for the SatisFactory tools, the SatisFactory platform will be able to guide the operators, even those with little experience, to perform all the necessary actions, all the steps of the solution package, for the proper preparation of the pilot plant. This will enhance the safety during the procedure, since detailed guidelines will be given, the efficiency of the whole procedure and the attractiveness of the shop floor to the new employees. Furthermore, the actors will gain confidence performing all these complicated actions will less effort.

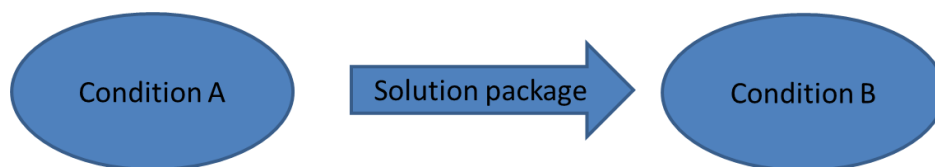


Figure 51 Change operation conditions to the pilot plant through a solution package

The number of the required actions that are needed to be executed in order for the process configuration to be suitable for the new operation will be given from the process supervisor, along with the detail for each action. In this application scenario, since different gases are going to be used in the new operating conditions, the calibrated mass flow controllers along with the appropriate gas bottles need to be installed. Moreover, the automation system variables and alarm bounds have to be updated, while the method on the chromatograph also needs to be changed. Finally, the last action of the procedure before the pilot plant is ready to be used in the new operating conditions, is to perform pressure tests using helium in order to detect possible leaks. The actor has the choice to ask something to a more experienced actor through the collaboration platform, while he has started to perform the necessary steps. He can also upload to the collaboration platform some details or something else that he values as important. This way, the next time that this same procedure will be performed, the involved actor will have this information as an extra tip.

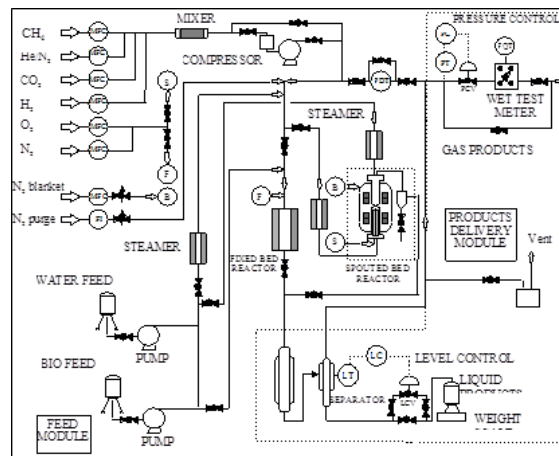


Figure 52 Flow diagram from a pilot plant at CERTH

Table 41 CERTH Application Scenario 3 characteristics

Application Scenario #	BSC-5.3
Application Scenario Name	Reconfiguration of process flow and actions for flexible redesign of production procedures
Version/Author	V1.0 / CERTH/CPERI (CZ)
Goals	Improvement of process work flow for the reconfiguration of a multipurpose unit
Type	Scheduled actions
Challenges	The challenges are to reduce the time needed for the pilot plant startup and to avoid delays and failures, during the reconfiguration between different workflow scenarios of a pilot plant. Immediate access to information about the new process flow on the shop floor. Upload to the collaboration platform of additional information or guidelines for this task in order to be helpful to future usage
Involved Actors	Maintenance team (manager, technicians: electrical, process, control) Process operators / Process supervisor
Pre-conditions	The operation of a pilot plant has finished and there is a need to start under different conditions
Post-conditions (Success Guarantees, Failure end conditions)	Success Guarantees: Readaptation of production based on upcoming experiment needs Failure end conditions: Increment of the workflow complexity of the experiments
Realization Concept	There will be a better documentation and implementation of the workflow procedures in order to be able to recognize the upcoming experiment needs. The new process flow can be viewed immediately and directly on the shop floor using augmented reality devices. This allows workers to map the process flow visualization directly to the physical environment.

Brief Description / Main flow	<p>Task collection and Definition Collection of the user's manuals of the pilot plants and any other document related. Examine along with the process operators the differences between the experiments and decide the needed actions.</p> <p>Work Planning – Design of the work After the collection of the necessary information, categorize the needed actions and create a task list for each involved actor.</p> <p>Work Scheduling After being sure that all the needed actions have been decided and that all necessary means are available (manuals, tools, manpower etc.), reserve the time slot to perform the reconfiguration process.</p> <p>Release – Assignment of the Work Order Having in mind the Scheduling sheet create a work order release and assign the available resources to the work orders backlog.</p> <p>Execution - Carry Out the Work All information from previous steps must be complete and available as well as the technological equipment and manpower. The steps of the procedures are carried out as written and shown on the tablets.</p> <p>Closure of the work order Check whether the reconfiguration process has completed successfully and that the pilot plant is ready to begin its operation according to the new experiment procedures.</p> <p>Production of Reports Compare the reconfiguration process existed before this scenario with the process that took place this time. In case of improvement, document the new procedures, inform and train the involved actors. In other case, re-examine the workflow process, create simpler task and try again to optimize the results.</p>
Frequency of use	Depends on the laboratory needs
Extensions or Alternate scenarios	Limited available resources for the decided changes (Manpower and hardware)
Trigger	Need for workflow changes in order to start different experiment. AR visualization is triggered when worker requests it
Duration	The duration varies between different pilot plants and different events
Stakeholders and Interests	Floor manager, maintenance supervisor
Special requirements	<p>Performance: The faster the workflow changes are completed the better</p> <p>User interface: The instructions must be clear and easy to follow from the involved actors</p>

5.4.2 BSC-6 Recognition of incidents regarding workers' movement (CERTH)

The sixth business scenario (BSC-6) concerning the shop floor of CERTH/CPERI is primarily focused on the safety of the workers. The extent of CPERI's pilot plants and the plethora of the necessary daily procedures impose numerous workers to spend most of their working time within the shop floor area. One of the goals of SatisFactory is to reduce the workers' time in the high risk shop floor area thus to increase their safety.

5.4.2.1 BSC-6.1 Recognition of incidents regarding workers' movement on the shop floor

The Application Scenario BSC-6.1 of CERTH refers to movement of workers at the shop floor of CERTH/CPERI. Many incidents mostly minor but sometimes major with many workers involved, could happen every day in an industrial shop floor. The purpose of this Application Scenario is to reduce the number of this kind of incidents. This will have a positive impact to the workers' safety, which is a main prospect for SatisFactory.



Figure 53 Movement tracking at CERTH/CPERI's shop floor through normal camera



Figure 54 Movement tracking at CERTH/CPERI's shop floor through depth camera

Minor incidents involving workers frequently occur, causing delays and/or difficulties to complete the performed actions. Identification of such incidents and their severity, along with automatically recalling knowhow based on previously occurred incidents and providing suggested actions, would be a substantial solution to the problem. There are some areas of the shop floor that need particular attention from the workers when they are moving inside them.

The safety of the workers is the main concept of this business scenario and the optimal usage of it is to predict safety related incidents regarding the workers' movement within the shop floor.

Table 42 CERTH Application Scenario 4 characteristics

Application Scenario #	BSC-6.1
Application Scenario Name	Recognition of incidents regarding workers' movement on the shop floor
Version/Author	V1.0 / CERTH/CPERI (CZ)
Goals	-Prevent minor incidents and/or accidents at the shop floor -Increase safety at the shop floor
Type	Scheduled – continuous actions
Challenges	The challenge is, through the movement recognition, to prevent possible accidents of the workers at the shop floor.
Involved Actors	Shop floor related actors
Pre-conditions	All of these data must be well-known: the location of the pilot plants, the exact schematics of the shop floor, the places where human entrance is forbidden or should be done very carefully, the exact location of the UWB devices placed at the shop floor, the workers' UWB ID, available wireless technologies and which environmental conditions leads to incidents
Post-conditions (Minimal Guarantees, Success Guarantees)	Minimal Guarantees: Movement recognition of actors and environmental data acquisition Success Guarantees: Successful preventions of incidents/accidents
Realization Concept	The system should have the continuous ability to recognize movement and environmental data on the shop floor. This requires good coaction between the software and all the related hardware parts. The precision must be at high levels in order to have the appropriate results.
Brief Description / Main flow	<p>Task collection and Definition Continuous communication between the system and the depth cameras. The data from the depth cameras are automatically imported to the system to be analysed.</p> <p>Work Planning – Design of the work The system must be able to identify every movement of the workers inside the shop floor area. The software of the system uses data from the depth cameras and the smart sensors and decides whether there is a movement or not.</p> <p>Work Scheduling The software of the system uses algorithms that can identify a dangerous movement inside a specific area. This operation is continuous and the system remains idle when there is no movement detection.</p> <p>Execution - Carry Out the Work When a movement is being identified, the system analyses the data, compares with the data being stored in the database and decides whether there is a possibility of accident or not. In case of danger, it recalls the workers' notify procedures in order to prevent the upcoming accident.</p> <p>Closure of the work order</p>

	<p>After the notification of the worker, the system checks again the position and the possibility of a new incident/accident. If the danger has overcome, the system becomes idle again and is waiting for new movement recognition. In case that the danger of an accident remains, it repeats the Execution step to notify the worker again.</p> <p>Production of Reports</p> <p>The maintenance manager is aware of all the preventing actions that the systems performs and evaluates the taken decisions. He also checks the workers' responses to the notifications of the system (To their tablets and glasses). He creates reports from the historical data.</p> <p>The floor manager is being informed in cases that accident did happened which the system didn't identify and he makes proposal for a better configuration of the system.</p>
Frequency of use	Continuous operation
Extensions or Alternate scenarios	Not Applicable
Trigger	Actors' movement detection from depth cameras. Abnormal environmental data from the smart sensor network.
Duration	Not Applicable
Stakeholders and Interests	Floor manager, Process supervisor, Maintenance manager
Special requirements	<p>Safety: Users must be always aware on the notification means</p> <p>Performance: All kind of notifications to the users must be immediate and clear</p>

5.5 *ROLE OF SATISFACTORY FOR SELECTED OPERATIONS AT A SHOP FLOOR WITH PILOT PLANTS FOR CHEMICAL PROCESSES*

The operation of the pilot plants must not be interrupted due to malfunctions but when it does, the restore has to be immediate. Thus, there has to be an online system that collects information about the pilot plants and responds when necessary. The time for restoring a malfunction will be minimized along with the possibility of errors.

The role of SatisFactory is to provide a set of tools the will improve the daily operation as performed at the shop floor. The interaction between actors with different roles (workers, supervisors, technicians, managers) in real-time has been accomplished with the collaboration platform. A prevention action plan will be derived in collaboration with a maintenance plan that involves various levels workers and tasks. The final incident notification system and active safety system has been tested, while a number of incidents in a controlled environment have been applied. For an initial evaluation of the line operation the generated events have been fed to the DSS system and appropriate signalling of conditions will be communicated to the associated actors at role basis.

Besides the personalized and parametric event notification, the response of the involved actors has been further analysed with respect to the time constraint posed by the severity of the event or alarm and the effectiveness of the supervisory information has been evaluated and fed back to the system in order to optimize the SOP which have been created.

The workers that daily perform actions at the shop floor must be very well trained and have great knowledge about the procedures and the components of the pilot plants, which is something very difficult and stressful due to the complexity there is. A system that would help and support workers, either by presenting them useful information about specific tasks or inform them about malfunctions would have great effect on the overall operation of the shop floor. Visual representation of important information regarding the status of the process, the steps of a standard procedure or the nominal state or status of a device or the component will be great support to the workers. All the above will also have positive effect to the safety of the shop floor and to the satisfaction of the workers. The SatisFactory platform is able to perform all the above actions, having as result the increment of the satisfaction of the workers at all the three shop floors of the project. Figure 55 shows the implementation roadmap for the aforementioned scenarios at CETH/CPERI shop floor.

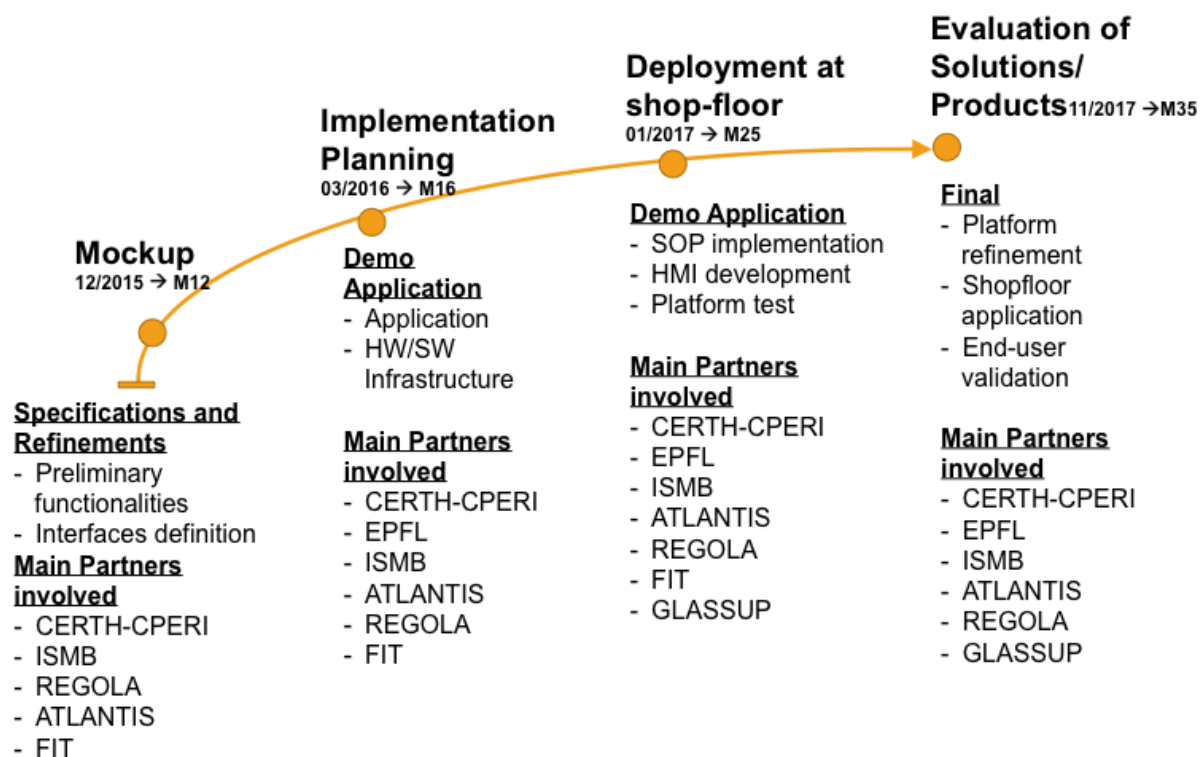


Figure 55 Roadmap for implementation of CETH/CPERI scenarios

5.6 IMPLEMENTATION OF THE APPLICATION SCENARIOS

The implementation of the application scenarios has been separated into two phases. The first phase included the implementation of the Application Scenarios at the shop floor of CERTH. The purpose of this was to locate possible problems or improvements of the scenarios, to correct them upgrading all the necessary components and procedures and test them again. The second phase included the implementation of the scenarios at the other two shop floors having as a feedback all the knowledge gained from the first phase. At some point, these two phases were simultaneously functioning due to the corrections and improvements that were needed. The following table presents the result of the implementation of the application scenarios at the three shop floors.

Table 43: Implementation of application scenarios

Application Scenario	Name	Shop floor	Selected/Implemented
BSC-1.1	Manual assembly operations with focus on Robot Wrist assembly	COMAU	Yes
BSC-1.2	Automated assembly operations with focus on Welding Gun assembly	COMAU	No
BSC-2.1	Remote Assistance	COMAU	Yes
BSC-3.1	Preventive and corrective maintenance management system	SUNLIGHT	Yes
BSC-4.1	Motive power battery assembly line	SUNLIGHT	Yes
BSC-4.2	Monitoring of the Cell Temperature during Jar formation and data collection	SUNLIGHT	Yes
BSC-4.3	Training platform for production process motive power batteries assembly line	SUNLIGHT	(merged to BSC-4.3)
BSC-5.1	Repair or restore an electromechanical malfunction	CERTH	Yes
BSC-5.2	Startup procedures for pilot plants	CERTH	Yes
BSC-5.3	Reconfiguration of process flow and actions for flexible redesign of production procedures	CERTH	Yes
BSC-6.1	Recognition of incidents and path optimization for workers movement on the shop floor	CERTH	Yes

It can be seen that most of the initial scenarios were selected to be tested at the shop floors. The final selection was based on the workers feedback and the evaluation of the added value that the specific scenario would bring to the shop floor at long term.

6 USE CASES DEVELOPMENT – METHODOLOGY AND MODELS

In software and systems engineering, a Use Case (UC) is a list of steps, typically defining interactions between the actors and the system in order to achieve a goal. The involved actors can be a human or an external system. Typically UCs are used at a higher level, representing missions or stakeholder goals. This chapter focuses on the methodology and the detailed description of Use Cases of the three shop floors of SatisFactory. Based on the information from the analysis of previous chapters and on the standard methodology, the Use Cases have been created, analysed, connected with the requirements and the actors. In this section, there is a definition of what will be tried to be achieved in SatisFactory in order to increase satisfaction and safety of the involved workers. Figure 56 depicts the content and activities of Chapter 6.

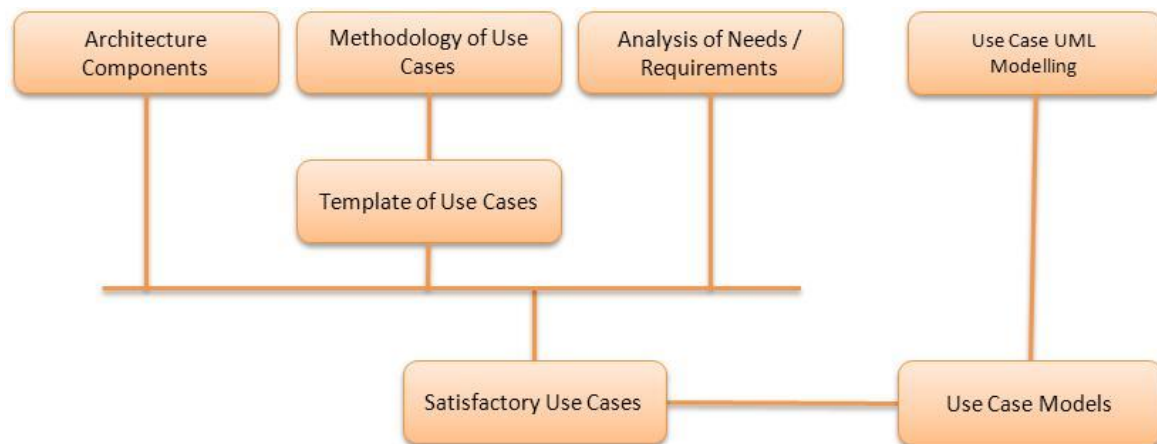


Figure 56 Content and Activities of Chapter 6

The aim of this chapter is to describe specific UCs where all collaboration, satisfaction and safety related aspects that are identified and categorized. The contribution of this Chapter is twofold. Firstly, the methodology adopted, encompass project results so far and can serve as guidelines while investigating collaboration, safety, training and data fusion context. Secondly, the UCs descriptions function as hands-on approaches to real life situations that involve key issues on SatisFactory objectives. They also facilitate the understanding of what situations are likely to emerge through different combinations of augmented reality assisted technologies and collaboration goals thus providing a deeper insight into complex and frequently opaque interconnections. By putting it all together this Chapter is a comprehensive guide towards the better understanding of the wider UC context addressed.

There have been many changes for the second version of the Deliverable D1.2 regarding the Use Cases. Firstly, all the existing Use Cases have been revised according to the revision of the Business Scenarios and according to the needs that came up since the first version of the Deliverable D1.2. In addition to that, two new Use Cases have been added (UC-4.5 and UC-5.4) to cover the same new needs that came up. Two new diagrams for each Use Case were added (e.g. Figure 61 and Figure 62 for UC-1.1) in order to have a better description of the Use Cases and a better presentation of the

relationship of each Use Case with the other Use Cases, the Business Scenarios, the components and the Actors of SatisFactory. This detailed analysis is very helpful for better understanding of the functionalities of the project. But, it is also necessary to all technology providing partners for the implementation of SatisFactory components because it clarifies all the details and the needs of the Use Cases. The results of this analysis will be used as an input in other deliverables, like D5.3, which are dealing with the implementation phase of SatisFactory Components.

6.1 METHODOLOGY FOR USE CASE INFORMATION GATHERING

The goal of this subsection is to analyse the methodology for the development of the Use Case, which is expected to provide guidance to forthcoming stages of the SatisFactory project in the definition of the usage of the SatisFactory architecture, its multiple components and ultimately the implementation of the SatisFactory platform. The specification of the Use Cases has followed a user - driven methodology, as illustrated in Figure 57.

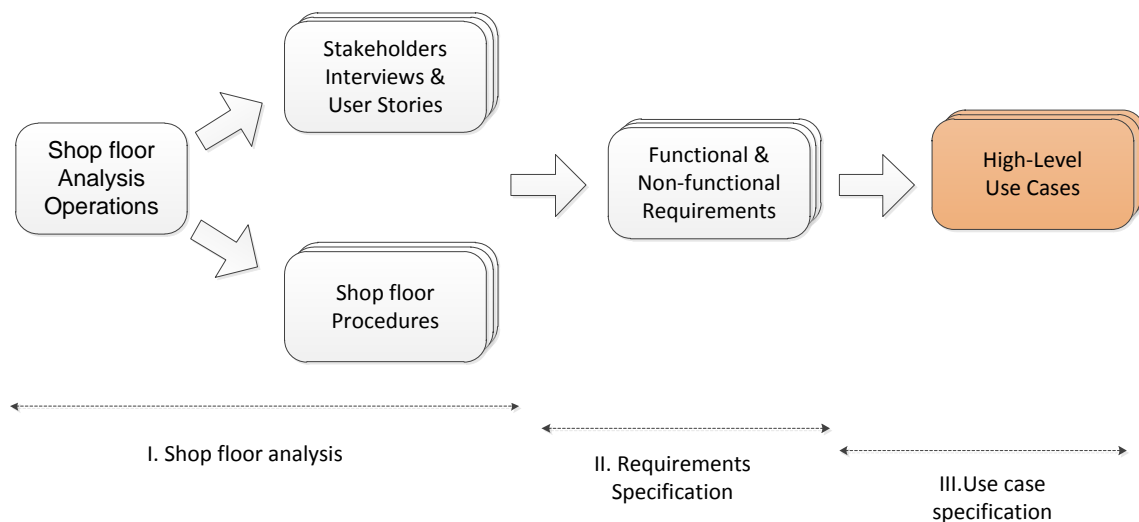


Figure 57 Use Case Determination

The UC specification process included three basic phases, which can be briefly described as follows:

- I. **Shop floor Analysis:** the initial phase corresponded to the definition of stakeholders and actor roles, as well as the description of a number of illustrative operations and user interviews based around the SatisFactory system. The outcome of this work can be found at deliverable D1.1.
- II. **Requirements specification:** based on the users' interviews and the identified procedures defined in the previous step, an initial set of requirements, addressing different domains, has been identified and specified.
- III. **Use case specification:** this phase included the specification of a number of use cases, describing the interactions between actors and the system, which are applicable to the shop floors identified before.

At this stage, UCs correspond to a statement of shop floor procedures, avoiding as much as possible any implementation bias that may somehow constrain or influence the technical design of the system. It should be noted that these candidate UCs apply to the SatisFactory system as a whole and a specific connection is made about which system components are utilized by each UC, which will be analysed in subsequent chapter of this deliverable.

UCs describe the sequence of interactions that take place between the involved stakeholders (which have been identified in Chapter 4) and the shop floors, to perform some actions. Thus, each actor is supposed to have an association with at least one UC. Some aspects of the UCs are expected to be further refined as the project progresses. It is assumed that relationships between actors have been established prior to the execution of the UCs, including the definition of the applicable procedures and actors profiles. The following section provides details about the templates that were used describing the manufacturing/batteries/chemical processes. The UC technique is used to capture current actors, existing system components (also denoted as actors), UCs and interactions among them. To extend the description of the current processes in detail, UC narratives and UC diagrams methods will be used.

6.1.1 Generic Description of Use Cases

UCs are dealing with using the system, which is related to the shop floor operations and the environment where the operations are performed. This recognises that UCs are created and organised in order to represent how people interact with the system. For SatisFactory the customers of the UCs are the involved actors that represent the identified groups of workers as seen from the previous chapter. So a UC is a way in which an actor, or some other interested stakeholder, can make use of the business to get the result they want, whether it's to perform an activity, to interact with co-workers or retrieve information for procedures. Therefore, the ultimate goal will be to describe the behaviour and response of the various actions performed by the involved actors.

The UC approach is a methodology usually used to managing system requirements, i.e. their identification, clarification and organization. The UC is made up of a set of possible sequences of interactions between systems and users in a particular environment and related to a particular goal. The UC should contain all system activities that have significance to the users. UC can be thought of as a collection of possible scenarios related to a particular goal. Each UC focuses on describing how to achieve a goal or perform an operation. UCs describe functionalities that define how actors interact with a system. The system could theoretically be anything, but in SatisFactory. The term "use case" is often a short version of "use case narrative" or "use case flow of events" and is depicted as an oval in the UC diagram, see Figure 1. A UC is described by the following characteristics:

- Organizes functional requirements
- Models goals of the system/actor interactions
- Records paths (called scenarios) from trigger events to goals
- Describes one main flow of events (also called a basic course of action), and possibly other ones, called exceptional flows of events (also called alternate courses of action);
- It is multi-level, so that one UC can use the functionality of another one.

UCs are used as an essential input to identify roles and deliverables in the specific domains (automotive manufacturing, batteries, chemical processes). As such, it consists of actors and systems that interact within the specific domains, and UCs containing sequences of events, through which the actors interact with the domain elements to get their job done. Altogether, the actors and the UCs describe who is involved in the current activities and how these activities take place. The development of the Use Cases follows a set of rules:

1. Actor definition. Actors interact directly with the system and can be humans, systems, or event/time triggers
2. Goal definition for the involved actors
3. Starting point definition. A trigger or an event
4. Stakeholder identification and their interests
5. Documents the Use Case. Work from the starting point towards completing the actor's goals. Be specific about task, sub tasks, context and the actor's motivations to complete the goals.

6.2 TEMPLATE FOR USE CASES

The UCs described in this chapter have been identified with the primary objective of motivating concepts and innovations expected through SatisFactory project, in order to address existing issues or barriers related to the knowledge sharing and the collaboration of actors among the various locations at the shop floor. Also, these UCs have been selected to better highlight the functional and nonfunctional requirements of the SatisFactory architecture and the developed SatisFactory platform.

There is no standard template for describing UCs that is effective for all application domains. Nevertheless, the SatisFactory partners have decided to adopt a template that incorporates the identified work flow steps from Chapter 4. The approach also covers some general guidelines available in the literature (Cockburn, 2001). The template that was used for the detailed description of the Use cases is depicted at Table 44.

Table 44 Template for Use Cases - Mandatory fields

Use Case #	<i>Please enter a Use Case ID</i>
Use Case Name	<i>Please enter a Use Case name</i>
Version/Author	<i>Stage the use case has reached / Who documented the Use Case</i>
Brief Description	<i>Please enter a brief description of this Use Case</i>
Assumptions or Pre-conditions	<i>Preconditions specify the conditions that must hold true before the scenario of the use case starts and will not be checked again after that.</i>

Post-conditions	<i>Post-conditions specify what must have been achieved at the end of a successful Use Case</i>
Goal (Successful End Condition)	<i>Determine the goal of the use case</i>
Involved Actors	<i>Define the actors involved in the use case. The same actor may play two different roles in the same use case</i>
Use Case Initiation	<i>Typically this will be an interaction between a user and the system. There may be Use Cases where their initiation comes from an external system</i>
Architecture Components Involved	<i>Please enter the Architecture Components involved in this Use Case</i>
Related Business Scenario	<i>Please enter the IDs of the Business Scenarios that are related with this Use Case</i>
Relationship with other Use Cases	<i>Please enter the IDs of other UCs that may be related with this Use Case</i>
Addressed requirements of the system	<i>Please enter the SAFA IDs that are addressed in this Use Case</i>
Restrictions	<i>Please enter if there are any restrictions for this Use Case to be implemented or developed</i>

6.3 MODELLING OF USE CASES

Use case diagrams (i.e. using UML notations) will be delivered to outline all use cases that will be specified, involving in an iterative process end-users and developers towards bridging their gap. This Section will also use the findings of the actors' analysis and will further extend the UC to include solutions to be implemented and expected benefits, defining an initial framework for the technologies that will be implemented in the use case scenario. The initial UCs are presented to the partners within this project for comments and consolidation. The purpose of the use case diagrams is to:

1. Facilitate understanding of requirements of a system
2. Get an outside view of a system
3. Identify external and internal factors influencing the system
4. Show interactions among the requirements and actors

6.3.1 UML - Use Case Diagrams

Each UC will be modeled using UML Use Case diagrams that will represent:

- Performed Actions
- Interaction of actors with the system
- Interaction of the technological components with the system
- Content of information/Data that are exchanged during the performed actions

Use case diagrams are used to gather the requirements of a system including internal and external influences. These requirements are mostly design requirements. So, when a system is analysed to gather its functionalities use cases are prepared and actors are identified. In brief, the purposes of use case diagrams can be as follows:

- Used to gather requirements of a system.
- Used to get an outside view of a system.
- Identify external and internal factors influencing the system.
- Show the interaction among the requirements and the actors.

Use case diagrams specify the events of a system and their flows. However, a UC diagram never describes the implementation of the UCs. A UC diagram can be imagined as a black box where only the input, output and the function of the black box is known. An example of use case diagram is Figure 58.

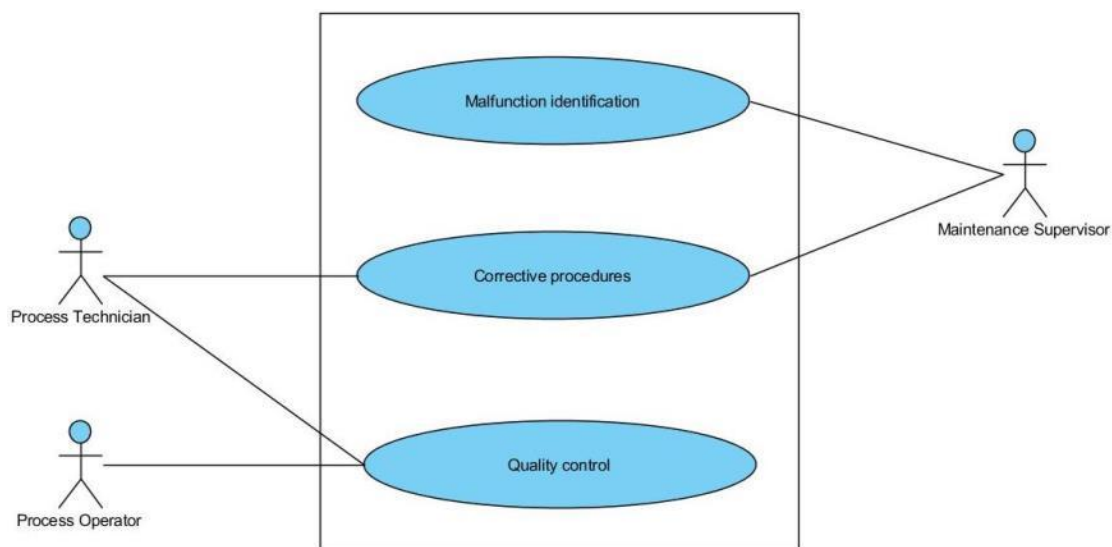


Figure 58 An example of Use Case diagram

The system boundary boxes (optional) is drawn around the use cases, to indicate the scope of the system. Anything within the box represents functionality to be demonstrated and connection with the actors. These diagrams are used at a very high level of design. Afterwards, this high level design can be refined multiple times to get a complete and practical picture of the system. A well-structured use case also describes the pre-condition, post condition and exceptions. These extra elements are used to make test cases when performing the testing. In order to identify the actors, we need to consider who or what uses the system, and which roles they play in their interactions with the system. Asking the following questions will help to identify actor.

- Who or what uses the system?

- What roles do they play in the interaction?
- Who installs the system?
- Who starts and shuts down the system?
- Who maintains the system?
- What other systems interact with this system?
- Who gets and provides information to the system?
- Does anything happen at a fixed time?

In terms of modeling actors, the following points are considered:

- Actors are always external to the system – these are therefore outside your control.
- Actors interact directly with the system.
- Actors represent roles that people play in relation to the system, not specific people.
- One person or thing may play many roles in relation to the system simultaneously or apart.
- Each actor needs a short name that makes sense from the business perspective.
- Each actor must have a short description that describes what this actor is from a business perspective.

A UC is something an actor wants the system to do. It is a “case of use” of the system by a specific actor:

- Use cases are always started by an actor;
- Use cases are always written from the point of view of an actor.

The best way of identifying use cases is to start with the list of actors, and then considering how each actor is going to use the system.

6.4 SATISFACTORY USE CASES

The goal of this Section is the definition of a wide range of Use Cases (UC), through which the innovative technologies and services of SatisFactory will be extensively evaluated. UCs will be defined for different type of users (workers, managers, decision makers in shop floor, etc.) and will follow a scenario-based gathering process that will comply with the IEEE guidelines (IEEE-Std-1471-2000). The process for drafting SatisFactory use cases will enable the consortium to capture, analyse and communicate end-user needs for the proposed technology in an effective manner.

6.4.1 Selection Methodology and Definition of Use Cases

The selection of the candidate Use Cases was achieved based on general requirements dictated by the project goals and on specific criteria that were derived from these requirements (see Deliverable D1.1). It was identified that a variety of contexts and types of activities should be addressed, a wide spectrum of actors should be involved and many different procedures are employed in the process. In order to ensure a global coverage of the needs and requirements a three step selection process was followed:

- Collection of candidate use cases through involvement of all project partners (end users and technology providing)

- Execution of a use case definition process
- Group review of results and discussion of selection for candidate UCs

The UCs that will be developed and implemented during SatisFactory project target both at daily and long term operation of the process units by providing:

- Active collaboration between the various levels of process related actors
- Online sharing of knowledge from the shop floor to both the process supervisor and the director that would improve the decision making procedure in terms of time, effort and global view of each unit
- Improvement of the planned maintenance actions by acquiring flow diagrams and electrical schematics depending on the unit, the involved subsystem or the device
- Efficient and fast response to unplanned events based on an augmented interface that acquires real-time information depending on the specific problem
- Minimize the safety related incidents which are caused by erroneous human actions.

The UC template for the candidate UCs was circulated to the end user partners (COMAU, SUNLIGHT, CERTH) of the project in the form of a detailed description with mandatory and optional fields. The process was run in order to collect feedback based on the specific aforementioned categories and overall project objectives. The process was completed and 21 UCs were defined and grouped into 6 main categories.

6.5 SATISFACTORY USE CASE ANALYSIS

This section analyses the Use Cases that are identified for the SatisFactory project. The UCs refer to the interactions of the actor groups and the architectural components of the SatisFactory project in order to perform a specific set of action or procedures. Some UCs illustrate the automated processes that take place initiated by the various events towards fulfilling the goals of the project. The following high-level UC diagram is used to describe a set of actions (use cases) that some systems (SF components) can perform in collaboration with one or more users (actors). Such diagram will be further analysed at the following sub-sections with detailed tables and UML diagrams. Overall six main categories of UCs are identified and each one handles different aspects of the systems and the requested actions or functionalities of the SatisFactory platform.

At the UML diagrams the components that are directly used by the specific UCs are being presented. This presentation made for simplicity and readability reasons of the diagrams. For example CIDEM is used in every UC but in some of them not directly but through another component of the architecture. This is not depicted at the following UML diagrams. The explicit connection for every component can be found in deliverable “D2.1 SatisFactory System Architecture” that deals with the detailed analysis of the architecture.

The Use Cases are interconnected with the general components of SatisFactory platform, as described at D2.1. A specific analysis of the usage of each component at the particular Business Scenarios will be performed at the respective deliverables D5.3 and D5.4, where the details of

implementation will be included. For example about the “Multi Modal & Augmented HMI” component the following note needs to be taken into consideration. This component has been cited many times in the description of several UCs but its description is too general. Although this could make difficult to assign specific responsibilities to the involved partners, the purpose of the Use Cases is to show that the group of components related to AR will be invoked. This component is integral part of several different parts of the architecture. To be specific, this happens with all the components belonging to the Service Layer; of course, one of the main goal of the architecture definition is to have different components following a single specification in order to make the HMI uniform to the end users. The single name: “Multi Modal & Augmented HMI” may cover different physical units, different interaction modes and different sets of information.

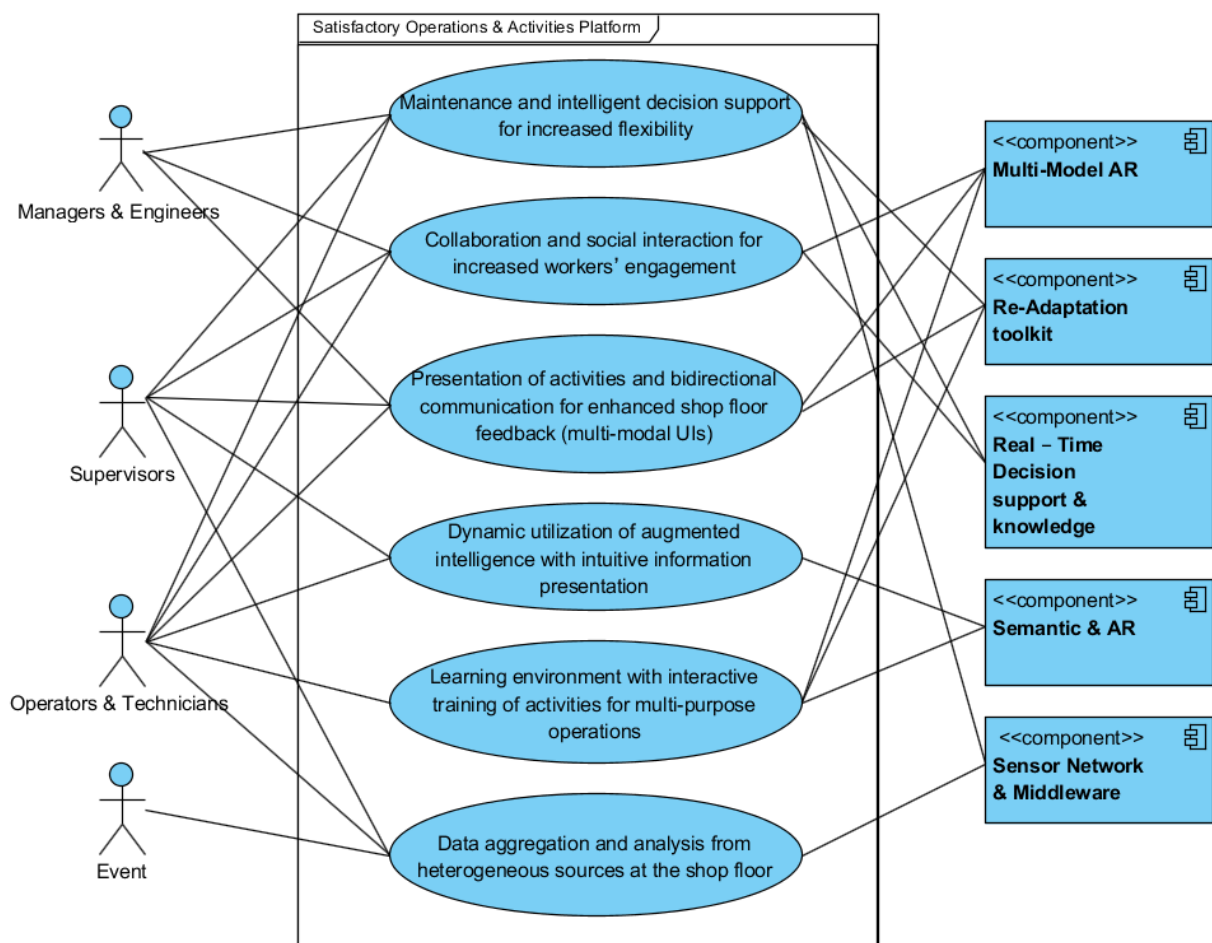


Figure 59 High-level Use Case diagram

For each of these categories a list of UCs is defined. In the following sections for each UC a high level UML diagram is provided along with the UC template where the details about the functionalities and features of the UC

6.5.1 UC-1 Data aggregation and analysis from heterogeneous sources at the shop floor

The first category of UCs is responsible for the implementation of the data aggregation and analysis from heterogeneous sources at the shop floor. This list of three UCs refers to the procedures that are responsible to gather data from the various systems on each shop floor. After collecting the data, they are being stored at the SatisFactory Repository in order to be analyzed and export the necessary information. This is a very critical point of the project because all the data from the shop floor are being evaluated here. The connection with the sensor networks must not be interrupted and the performed analysis must extract only the necessary information. A detailed analysis of these Use Cases is shown in the following figure.

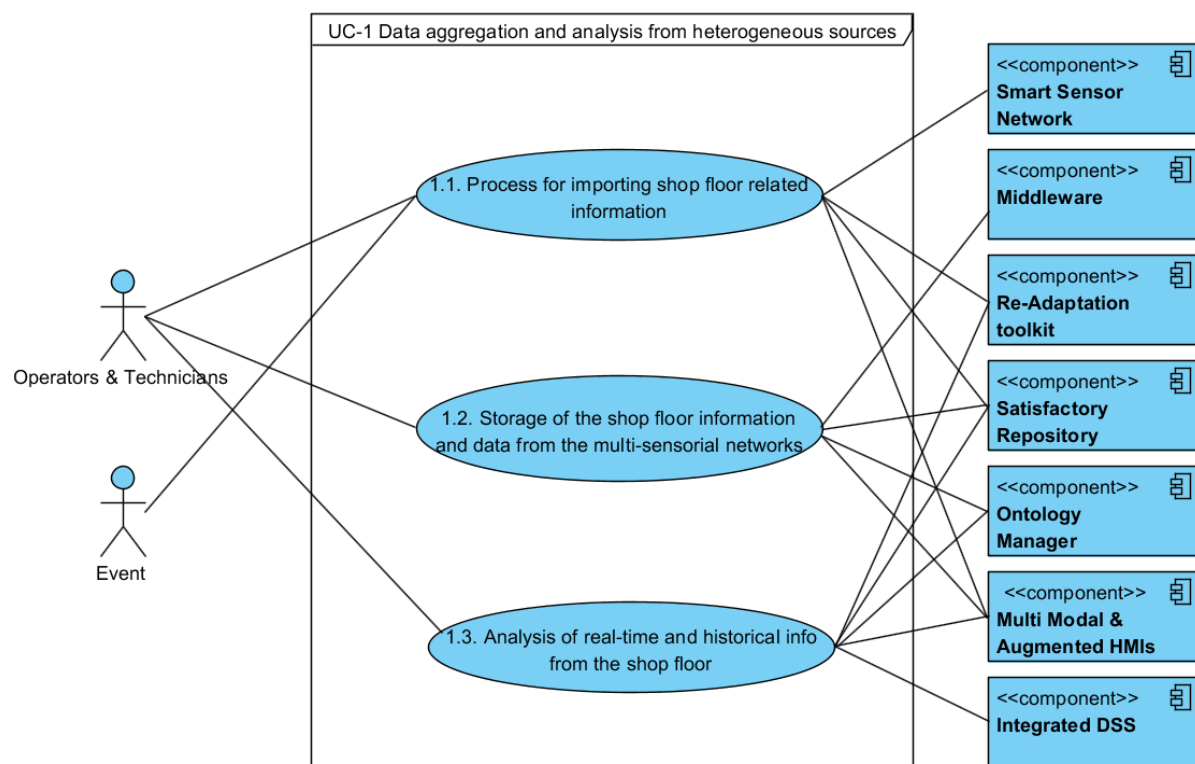


Figure 60 Analysis of UC-1

The following table is an analysis of the Use Case 1.1 according to the template that has been used.

Table 45 UC-1.1 Process for handling shop floor related information

Use Case #	UC-1.1
Use Case Name	Process for handling shop floor related information (data acquisition)
Version/Author	v2 / CETH/CPERI (CZ)
Brief Description	This use case refers to the ability of the involved actors to import and handle shop floor information related to the static characteristics of the asset- machinery-production data as organized at the repository and to modify operating procedures

	<p>that are implemented at the business scenarios of SatisFactory. The data should be in appropriate format or type supported by the SatisFactory platform. The actors use the Multi Modal HMLs to access the information which is already stored and perform the appropriate updates depending on the requested activities.</p> <p>Besides the actions triggered by the operators and technicians, at predefined time intervals the components of the Smart Sensor Network (SSN) (cameras, UWB wearable devices, AR glasses, other AR devices, dependable network infrastructure and automation systems) will initiate the actions for processing from the SSN towards the SatisFactory platform through the Middleware components (data or events). The Device Managers for each components are activated in a timed polling mode, a send/receive mode or based on an event.</p>
Assumptions or Pre-conditions	The components of the SSN are successfully integrated to through the Middleware to the SatisFactory platform.
Post-conditions	A filtered part of the information will be provided to the Ontology Manager and will be used for further analysis.
Goal (Successful End Condition)	The main goal of this UC is to provide the necessary functions for the processing of data from the SSN or shop floor related information. The data are successfully acquired from the shop floor using the Common Information Data Exchange Models (CIDEM).
Involved Actors	Operators & Technicians
Use Case Initiation	The UC is initiated with the integration of the devices and the corresponding hardware and software in conjunction with the communication from the existing system to the SatisFactory platform through the Middleware. This UC is automatically initiated in order to acquire the data from the SSN or upon request of the actors to import shop floor information.
Architecture Components Involved	Smart Sensor Network, SatisFactory Repository, Multi Modal & Augmented HMLs, Re-Adaptation toolkit
Related Business Scenario	BSC-1, BSC-2, BSC-3, BSC-4.1, BSC-4.2, BSC-5
Relationship with other Use Cases	UC-1.2, UC-4
Addressed requirements of the system	SAFA IDs: 232, 231, 230, 226, 224, 181, 115, 76, 73, 41, 34, 31, 24
Restrictions	Availability of the architectural map (shop floor plan) of the area under interest and communication network. Availability of the Common Information Data Exchange Models (CIDEM). Availability of the UWB Anchor coordinates at the shop floor. The forbidden zones have to be pre-defined in the CIDEM

The next two figures present the connection of the Use case with the SatisFactory components, with Business Scenarios and other Use Cases.

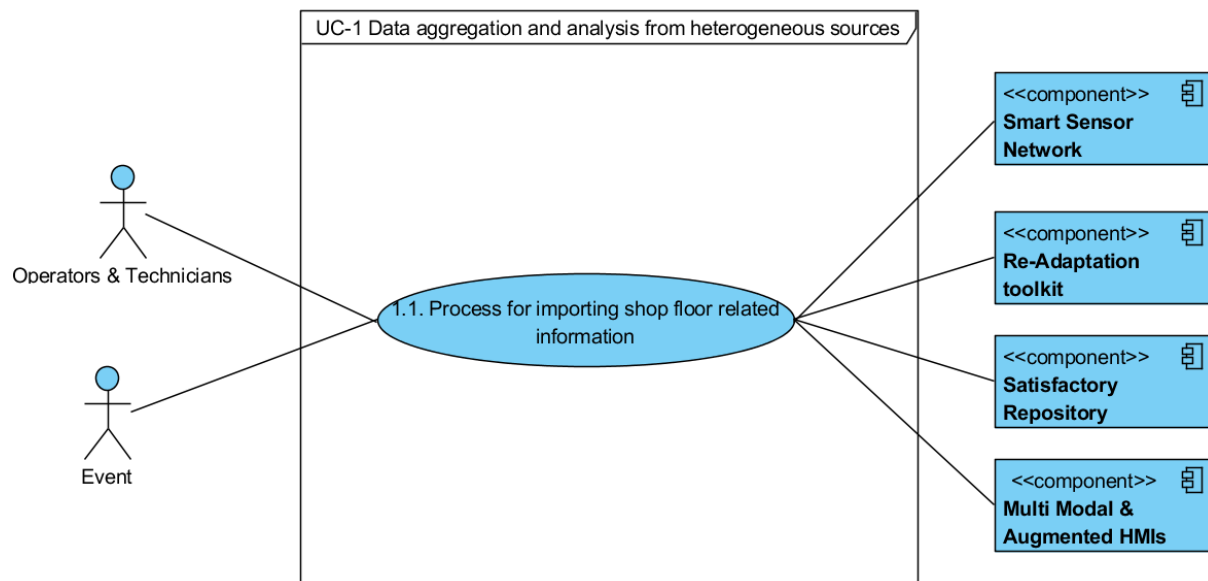


Figure 61 Analysis of UC-1.1

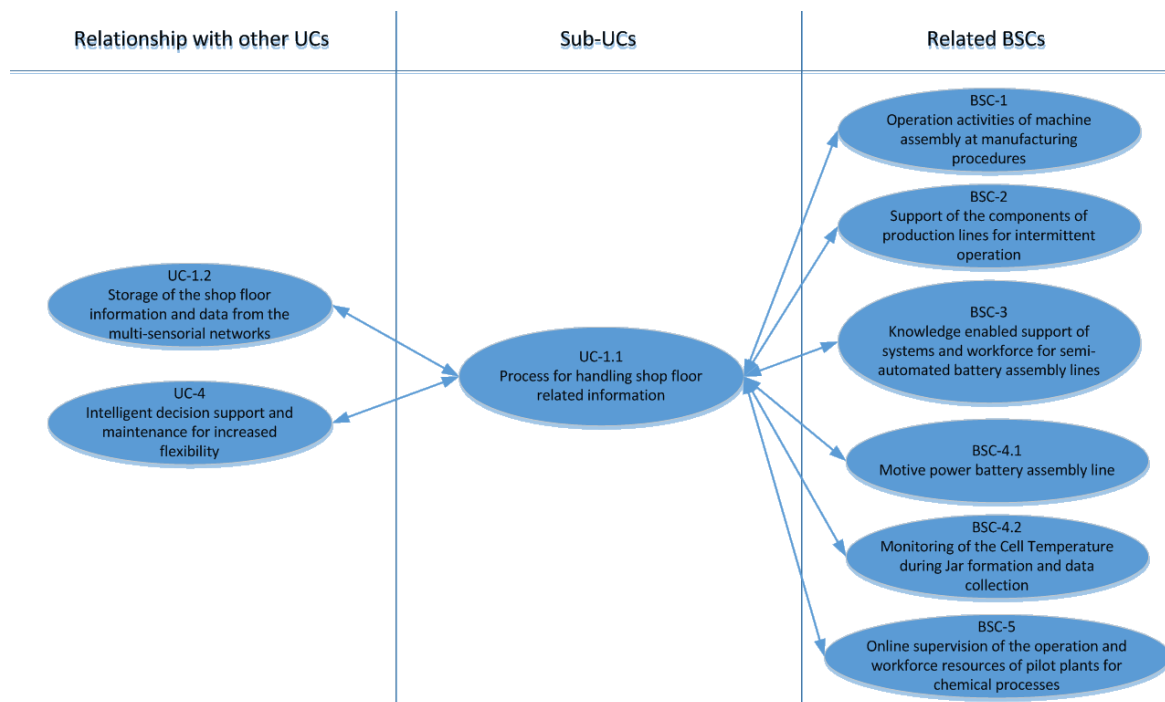


Figure 62 Relationship of UC-1.1 with other UCs and BSCs

At the following table there is an analysis of the Use Case 1.2 according to the template that has been used.

Table 46 UC-1.2 Storage of the shop floor information and data from the multi-sensorial networks

Use Case #	UC-1.2
Use Case Name	Storage of the shop floor information and data from the multi-sensorial networks (storage of data to repository)
Version/Author	v2 / CERTH/CPERI (CZ)
Brief Description	This UC is responsible for the analysis and processing of data and information from the shop floor. The UC stores the data to the SatisFactory repository through its communication with the middleware. The Common Information Data Exchange Model (CIDEM) and the Ontology Manager are respectively used to store and provide taxonomy of the data.
Pre-conditions	The Device manager can acquire the data from SSN and make them accessible through the Middleware core.
Post-conditions	The shop floor information and the data from the SSN are accessible and are organized based on the CIDEM schema.
Goal (Successful End Condition)	Successful storage of the shop floor related information and signal data (Asset-Machinery-Production Data, etc).
Use Case Initiation	This UC is initiated when data are available to the Middleware by the SSN or when an actor inserts/modifies information that are stored at the Repository using the information from the CIDEM schema.
Involved Actors	Operators & Technicians
Architecture Components Involved	Middleware, SatisFactory Repository, Ontology Manager, Multi Modal & Augmented HMIs
Related Business Scenario	BSC-1, BSC-2, BSC-3, BSC-4.1, BSC-4.2, BSC-5, BSC-6.1
Relationship with other Use Cases	UC1.1, UC1.3
Addressed requirements of the system	SAFA IDs: 230, 226, 225, 224, 76, 73, 41, 34
Restrictions	UWB radio connectivity can be affected by the harsh industrial environment for the UWB-based wearable devices and the transmission of their signals. UWB anchor nodes and a gateway have to be deployed in order to use the UWB-based localization system. The forbidden zones have to be pre-defined in the repository.

The next two figures present the connection of the Use case with the SatisFactory components and with the Business Scenarios and the other Use Cases.

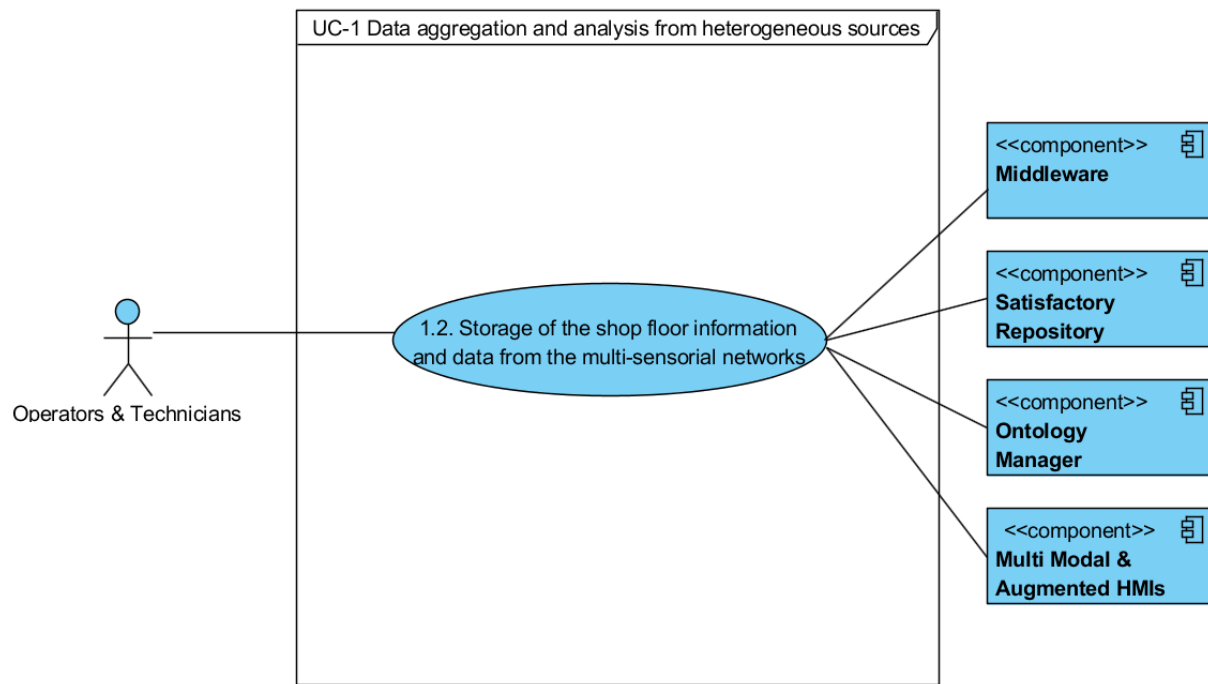


Figure 63 Analysis of UC-1.2

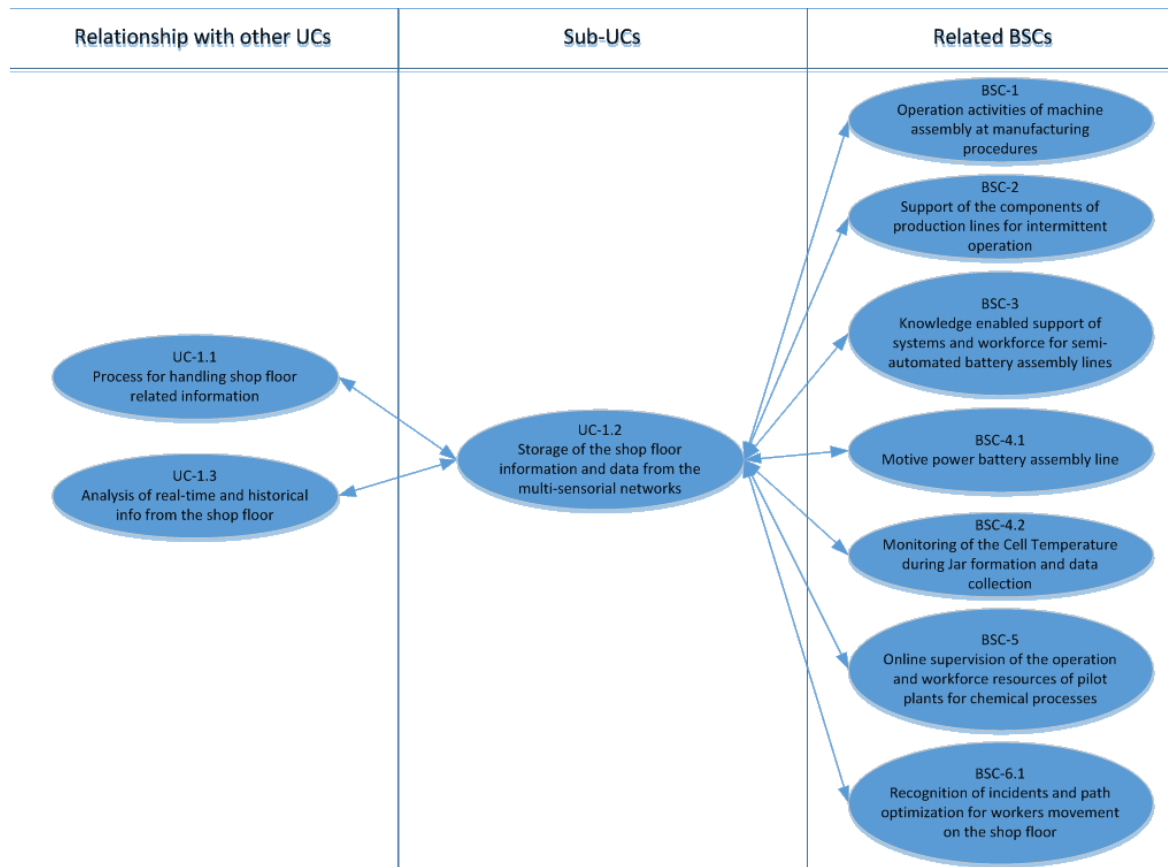


Figure 64 Relationship of UC-1.2 with other UCs and BSCs

At the following table there is an analysis of the Use Case 1.3 according to the template that has been used.

Table 47 UC-1.3 Analysis of real-time and historical info from the shop floor

Use Case #	UC-1.3
Use Case Name	Analysis of real-time and historical info from the shop floor
Version/Author	v2 / CERTH/CPERI (CZ)
Brief Description	The UC refers to the functionality of the system to analyse the dynamic data as stored or the online data as the events, procedures and activities are evolving or changing in real-time at the shop floor. The Ontology Manager through the information stored at the Repository is able to provide information based on predefined views in cooperation with the Integrated DSS. This UC refers to the ability of the SatisFactory platform to process the information from the Smart Sensor Network and to identify meaningful events that will be utilized later by the training, decision support, operational platform and incidents detection and visual

	analytics components of the system.
Pre-conditions	The Multi Modal component is interconnected with the Facilities Layer of the SatisFactory platform. An active connection is established with the SSN when online analysis is requested for the status of the involved equipment or system. All data needed for this process are stored (already or in real time through the middleware) in the SatisFactory repository.
Post-conditions	Analysis of the shop floor data as stored at the Repository for the specific time frame or specific area of interest.
Goal (Successful End Condition)	The main goal of this UC is to provide useful information from the analysis of online or historical data from the Repository, such as the status of the procedures or events that have occurred for a specific time.
Use Case Initiation	The involved actors send a request for data analysis for online or historical data. The analysis is activated upon actor's request and targets a specific procedure or production facilities based on their interests.
Involved Actors	Operators & Technicians
Architecture Components Involved	SatisFactory Repository, Ontology Manager, Multi Modal & Augmented HMIs, Integrated DSS, Re-Adaptation toolkit
Related Business Scenario	BSC-2, BSC-3, BSC-4.1, BSC-4.2, BSC-5.1, BSC-6.1
Relationship with other Use Cases	UC-1.2, UC-04, UC-03
Addressed requirements of the system	SAFA IDs: 76, 58, 41
Restrictions	The forbidden zones have to be pre-defined in the repository

The next two figures present the connection of the Use case with the SatisFactory components and with the Business Scenarios and the other Use Cases.

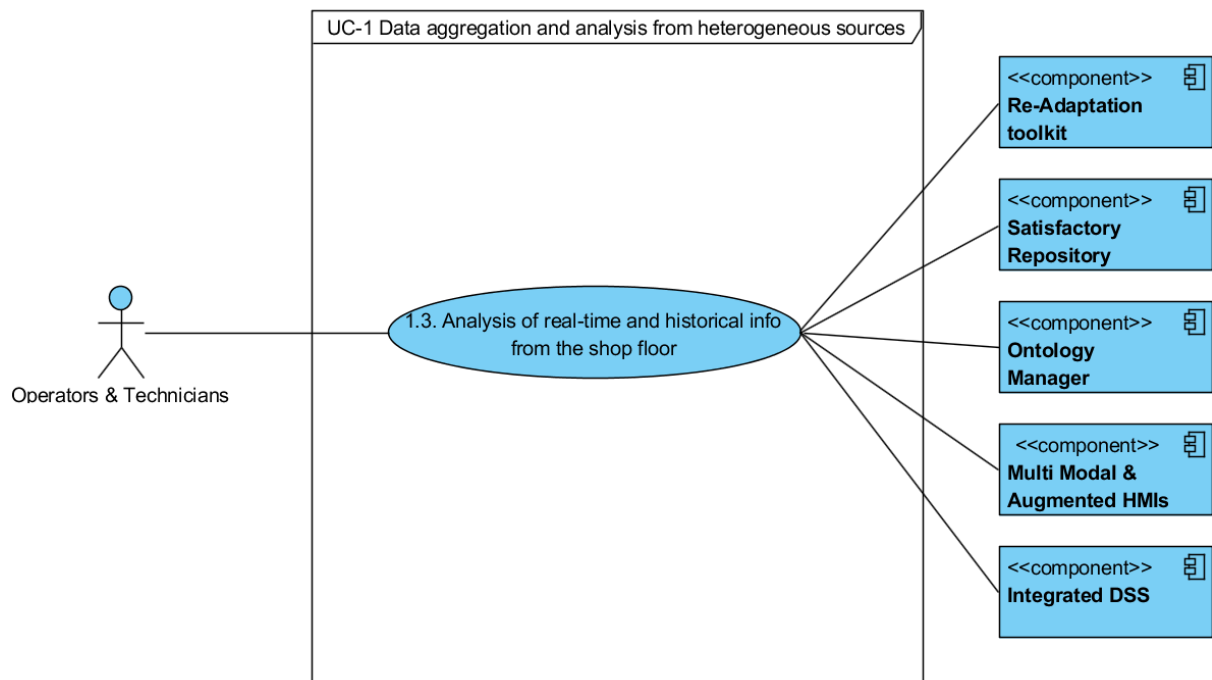


Figure 65 Analysis of UC-1.3

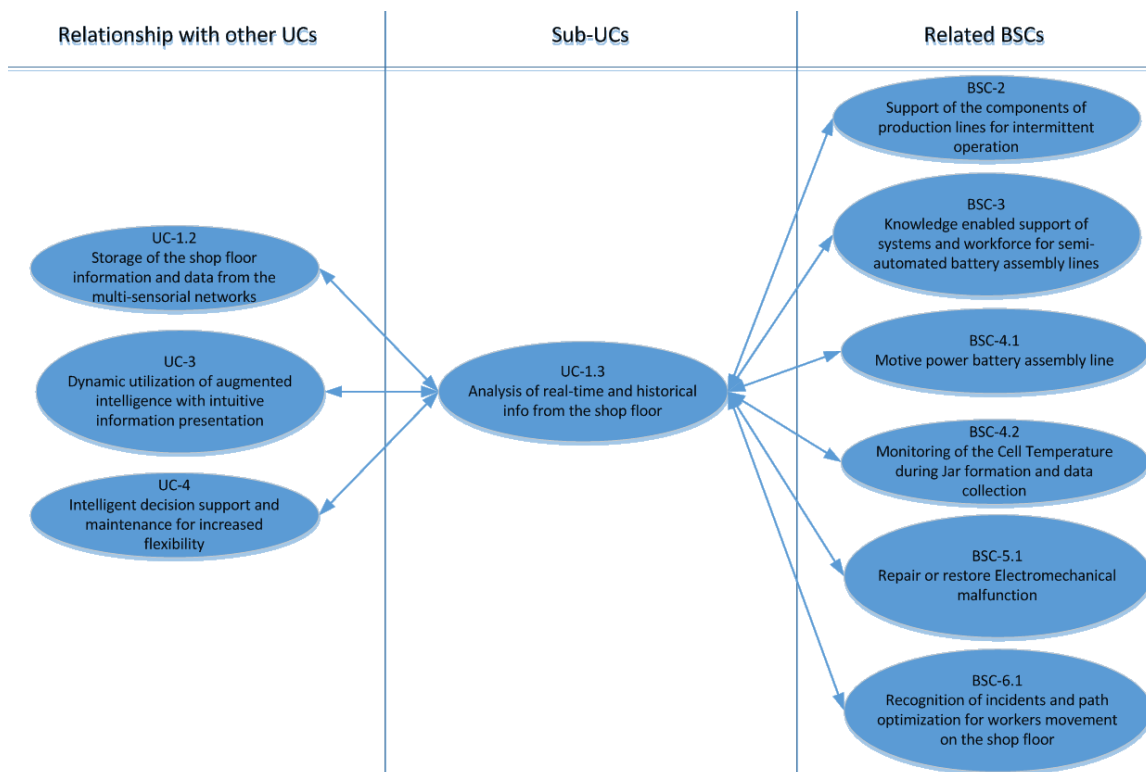


Figure 66 Relationship of UC-1.3 with other UCs and BSCs

6.5.2 UC-2 Learning environment with interactive training activities for multi-purpose operations

The second category of UCs deals with the learning environment about interactive training activities for the multi-purpose operations that are performed at each shop floor. This set of Use Cases refers to the educational part of SatisFactory. Through the Learning platform, the involved actors are able to perform training actions about on-the-job training or about presentation of maintenance and operational procedures. The following Use Cases help new workers during their training period and have the potential to assist workers on their daily actions. The main goal is to assist workers avoiding mistakes that lead to problems. The presentation of some procedures with many details through the AR devices is also a very helpful function that can save a lot of time and effort.

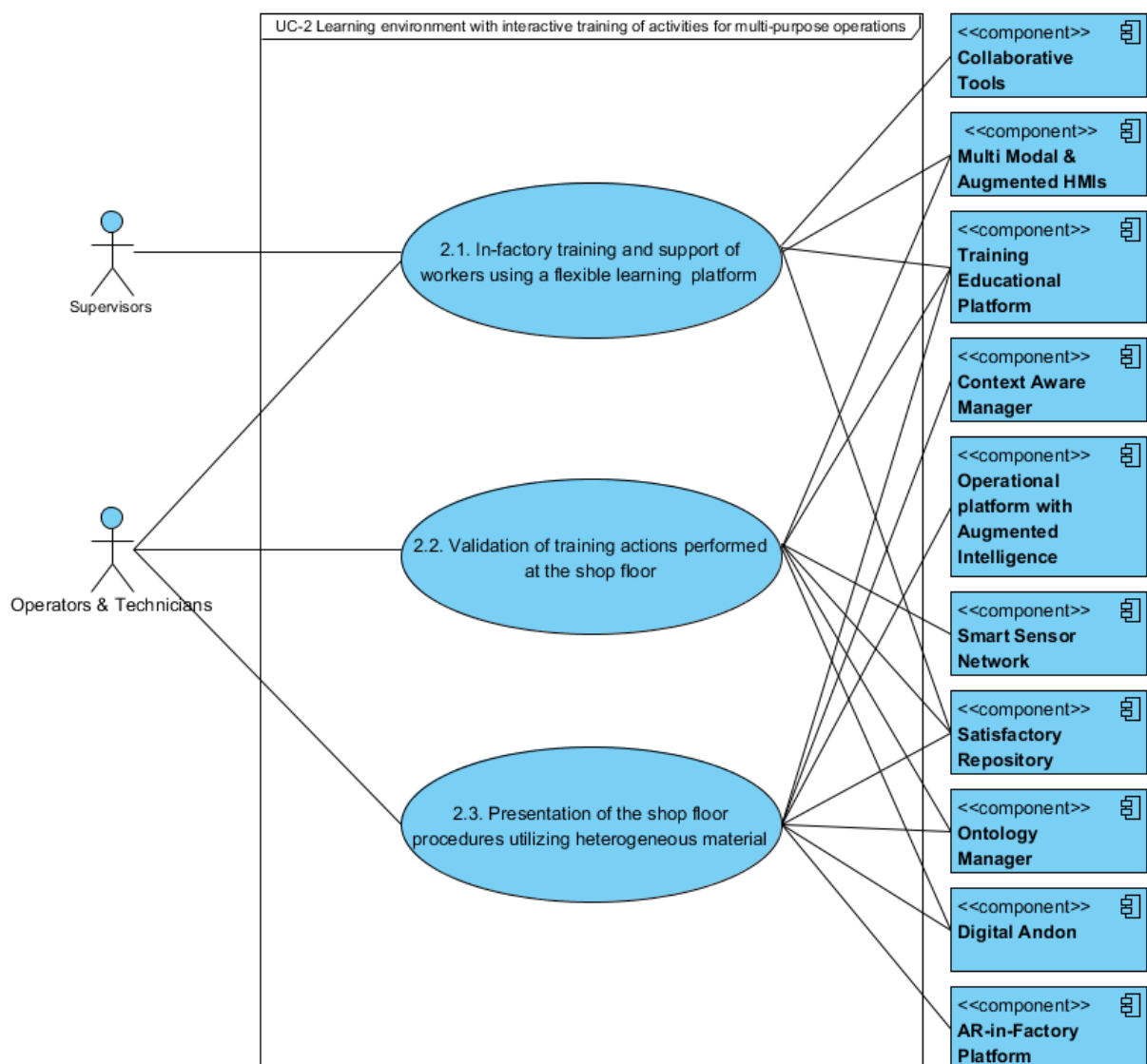


Figure 67 Analysis of UC-2

At the following table there is an analysis of the Use Case 2.1 according to the template that has been used.

Table 48 UC-2.1 In-factory training and support of workers using a flexible learning platform

Use Case #	UC-2.1
Use Case Name	In-factory training and support of workers using a flexible learning platform
Version/Author	v2 / CETH/CPERI (CZ)
Brief Description	<p>The Training and Educational platform (TEP) will provide a learning environment for the involved actors that would increase their knowledge and their competences at performing operating procedures. This UC will use the dynamically expanding and semantically-enhanced knowledge base in conjunction with the Collaboration tools using the communication platform.</p> <p>This UC will activate the training activities to be used by the Multi Modal and Augmented HMIs and the SSN components, which are involved at training (AR Glasses and Other AR devices). This UC is executed by the involved actors without the need of the continuous attention of an educator.</p>
Pre-conditions	The training procedures are described in detail and the respective Standard Operating Procedures are available and stored at the Repository to be used by the Operational Platform with Augmented Intelligence.
Post-conditions	The training procedures are performed successfully and the participating actors have concluded requested procedures as provided by the TEP
Goal (Successful End Condition)	When “on the job” training is performed the response to an abnormal event is reduced and the experienced workers are able to assist the novice worker from distance by providing through the TEP the necessary information.
Use Case Initiation	This U2 has two modes of usage, one related to the typical training using the virtual environment and the second is related to the “on the job” training activities. The Operators and Technicians will invoke the initiation of the training through the appropriate UI and the Training and Education platform will provide the necessary information to the involved actors.
Involved Actors	Operators & Technicians
Architecture Components Involved	Collaborative Tools, Training Educational Platform, Satisfactory Repository, Multi Modal & augmented HMIs
Related Business Scenario	BSC-1, BSC-2, BSC-4.1, BSC-4.3
Relationship with other Use Cases	UC-2.2, UC-2.3
Addressed requirements of the system	SAFA IDs: 187, 186, 184, 154, 118, 93, 79, 67, 66, 65, 58, 41, 40, 37, 32, 24, 19, 14, 13

Restrictions	-
--------------	---

The next two figures present the connection of the Use case with the Satisfactory components and with the Business Scenarios and the other Use Cases.

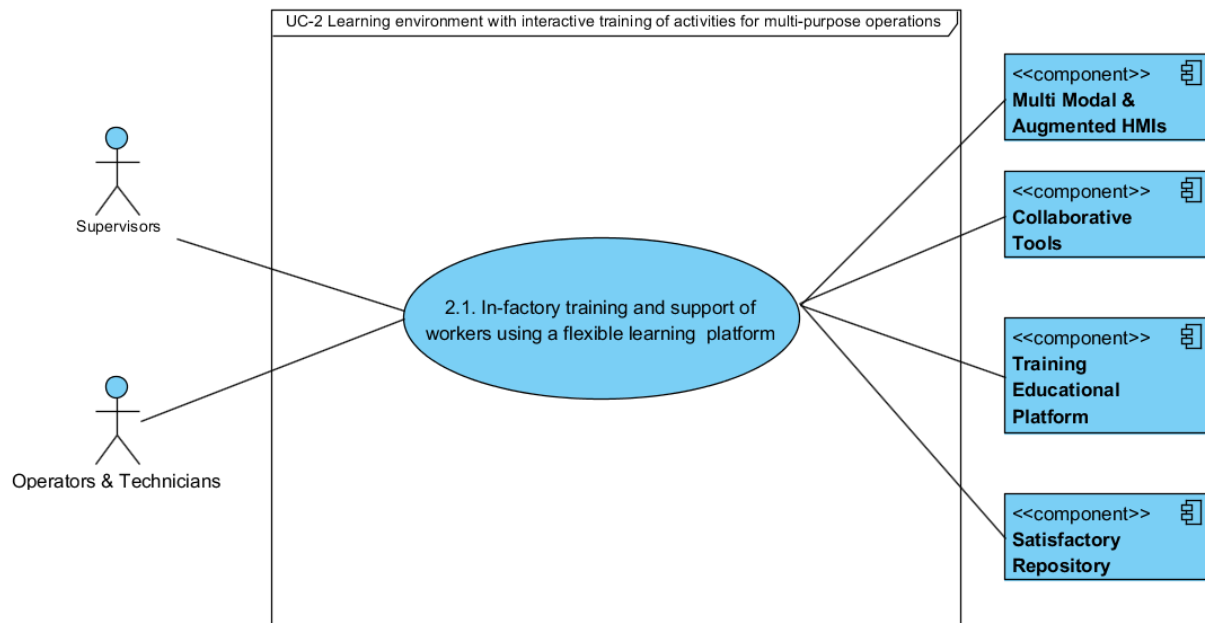


Figure 68 Analysis of UC-2.1

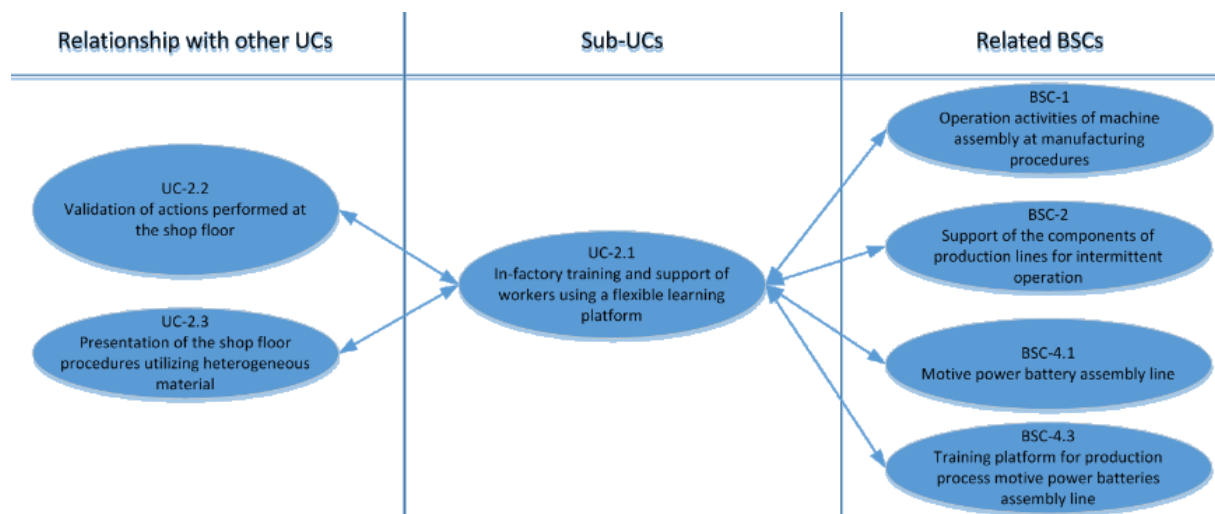


Figure 69 Relationship of UC-2.1 with other UCs and BSCs

At the following table there is an analysis of the Use Case 2.2 according to the template that has been used.

Table 49 UC-2.2 Validation of training actions performed at the shop floor

Use Case #	UC-2.2
Use Case Name	Validation of training actions performed at the shop floor
Version/Author	v2 / CETH/CPERI (CZ)
Brief Description	<p>This UC will validate the training actions that will be performed during the learning sessions. The proper or correct way for the completion of an activity or procedure will reside at the Training and Educational Platform (TEP).</p> <p>The TEP will identify the performed activity using the information from the SSN through the Middleware. The respective component that will be used by the TEP will evaluate the provided data and a proper feedback will be send to the TEP. Each action will be validated automatically where possible or manual by the operator and the results will be sent to the TEP.</p> <p>This UC can validate general actions that are performed by the actors. Besides the training context, actions that are documented and appropriately modeled can be checked for validity against specific measureable criteria of success.</p>
Pre-conditions	The training procedures are described in detail and the respective Standard Operating Procedures are available and stored at the Repository to be used by the Operational Platform with Augmented Intelligence. Also useful parts of these procedures are displayed by the Digital Andon.
Post-conditions	The TEP will receive the outcome of the validation processes performed by this UC and the actions under investigation will be tagged as successful or not successful.
Goal (Successful End Condition)	The actions are identified and the involved actors have performed the requested actions with success according to the predefined procedures as described by the SOP.
Use Case Initiation	This UC is initiated by the set of actions that the involved actors perform during their simulated training or by the on-the-job training activities.
Involved Actors	Operators and Technicians
Architecture Components Involved	SatisFactory Repository, Smart Sensor Network, Ontology Manager, Training & Educational Platform, Digital Andon, Multi Modal & augmented HMIs
Related Business Scenario	BSC-1, BSC-2, BSC-4.1, BSC-4.3, , BSC-5.1, BSC-5.2, BSC-6.1
Relationship with other Use Cases	UC-2.1, UC-2.3, UC-4.3
Addressed requirements of the system	SAFA IDs: 136, 118, 115, 58, 41, 40
Restrictions	There should be available (a) the architectural map (floor plan) of the area under interest, (b) TCP/IP network, (c) power supply.

	<p>Data Format availability.</p> <p>High speed data link, depending on desired bitrate, with remote site is available.</p> <p>Availability of the UWB Anchor coordinates at the shop floor. The forbidden zones have to be pre-defined in the repository</p>
--	--

The next two figures present the connection of the Use case with the SatisFactory components and with the Business Scenarios and the other Use Cases.

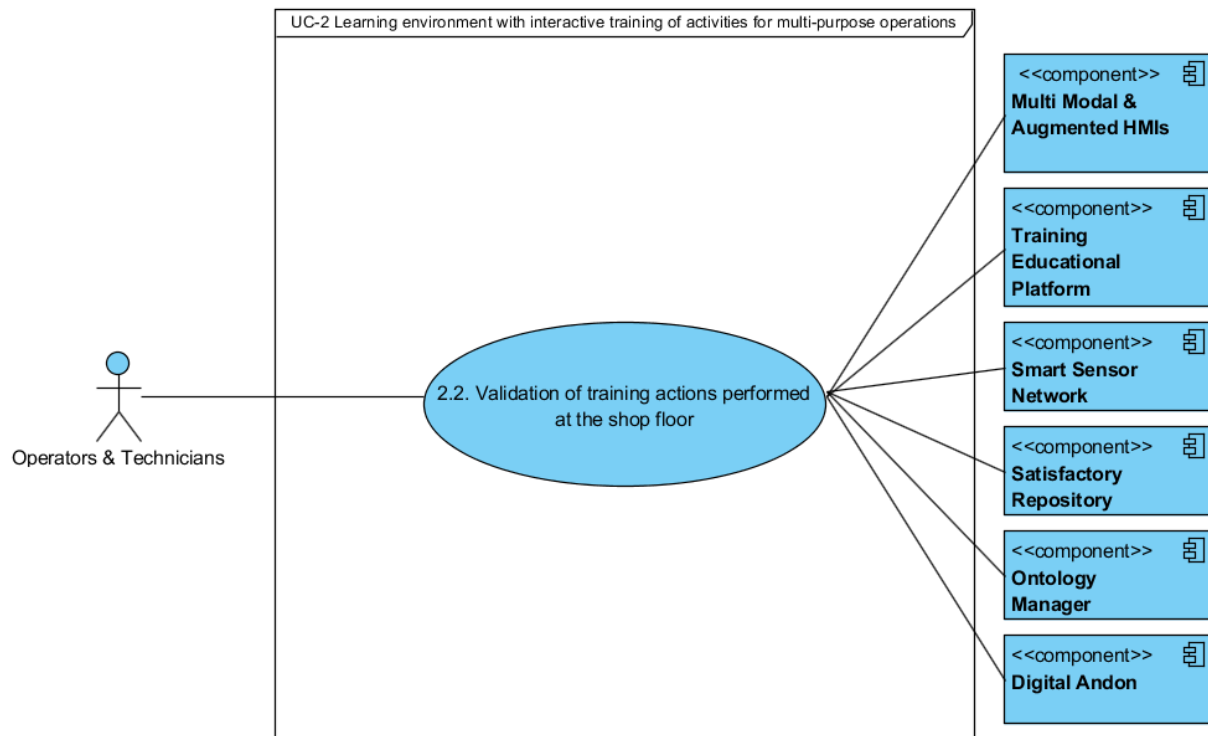


Figure 70 Analysis of UC-2.2

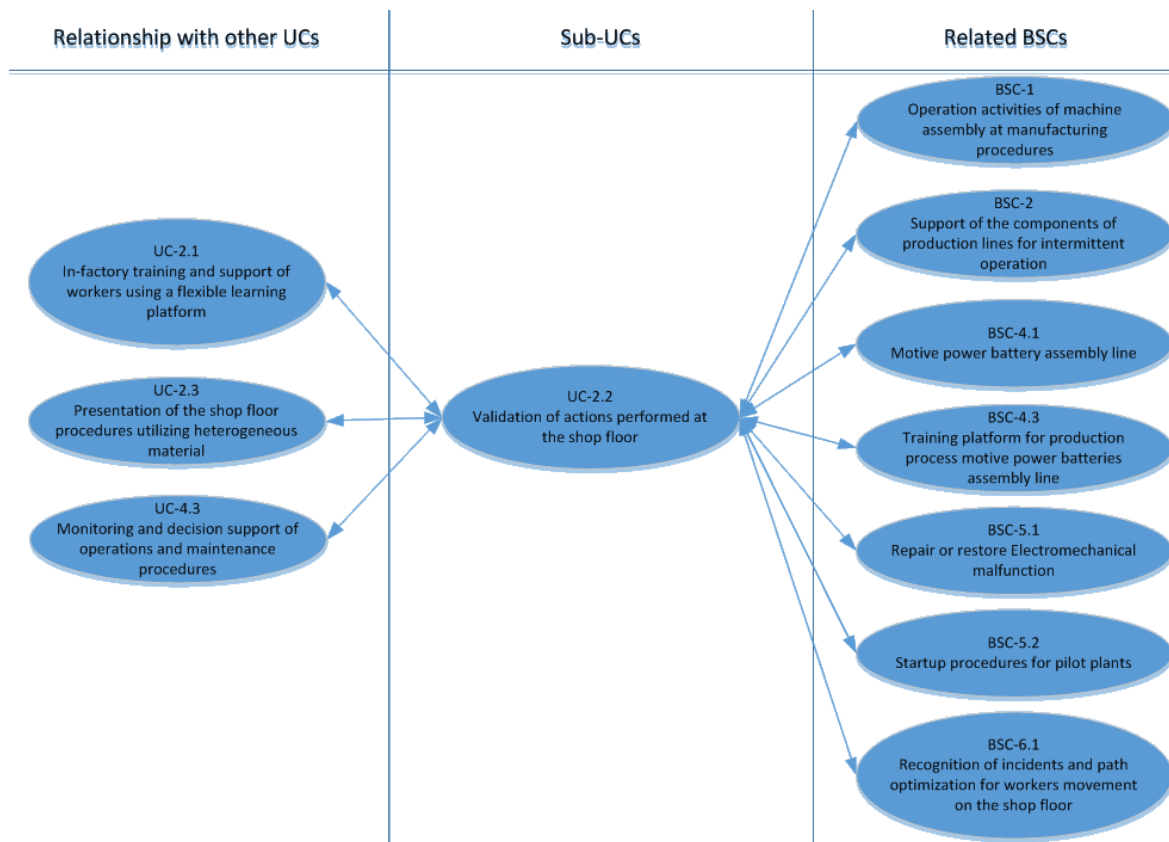


Figure 71 Relationship of UC-2.2 with other UCs and BSCs

At the following table there is an analysis of the Use Case 2.3 according to the template that has been used.

Table 50 UC-2.3 Presentation of the shop floor procedures utilizing heterogeneous material

Use Case #	UC-2.3
Use Case Name	Presentation of the shop floor procedures utilizing heterogeneous material (work orders, manuals, schematics)
Version/Author	v1 / CERTH/CPERI (CZ)
Brief Description	The main scope of this UC is to provide the necessary steps of actions related to the procedures as performed by the involved workers in order to utilize in an optimum way the stored information and knowledge as derived by the Ontology Manager and the Repository. The Operational Platform will be utilized in order to make available the necessary steps for the aggregation of the requested procedures upon request. The shop floor workers and technicians will have a detailed description using sources such as schematics, multiple-media content, manuals or standard operating procedures in combination with the historical information for each situation or event that they will be involved with. The activities of this UC will cover both the offline simulated training and the on the job training activities.

Pre-conditions	Formalized operating procedures. Any resources (images, 3d models, etc.) useful to describe the procedures themselves should be available and stored at the SatisFactory Repository to be used by the AR In-factory Platform.
Post-conditions	Presentation of the procedure step or procedure material. The response is evaluated by the actor.
Goal (Successful End Condition)	The requested procedure is presented to the actor and the necessary information, as stored at the Repository, is available.
Use Case Initiation	This UC is initiated by the TEP in response to the actor's activities. The actors request information about the procedures, partially or as a whole and the Operational platform provides them.
Involved Actors	Operators & Technicians
Architecture Components Involved	Operational Platform with Augmented Intelligence, SatisFactory Repository, Ontology Manager, Digital Andon, Context Aware Manager, Multi Modal & augmented HMIs, AR In-Factory Platform, Training Educational Platform
Related Business Scenario	BSC-1, BSC-2, BSC-4.1, BSC-4.3, BSC-5.1, BSC-5.3
Relationship with other Use Cases	UC-3.3 (acquire work schedules and sequence of actions) UC-6.4 (visualization of information at the AR Glasses)
Addressed requirements of the system	SAFA IDs: 229, 227, 187, 186, 184, 136, 115, 84, 67, 66, 65, 58, 41, 37, 24, 13

The next two figures present the connection of the Use case with the SatisFactory components and with the Business Scenarios and the other Use Cases.

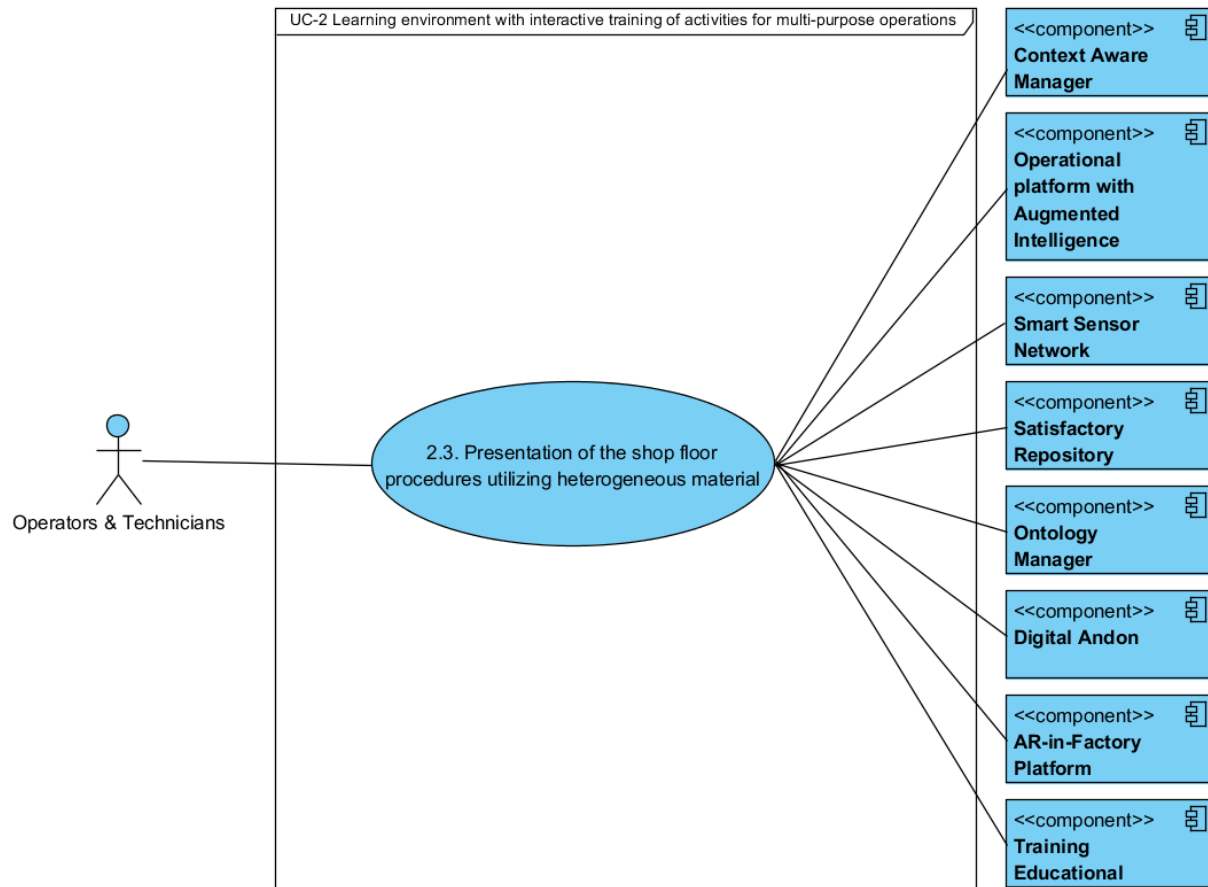


Figure 72 Analysis of UC-2.3

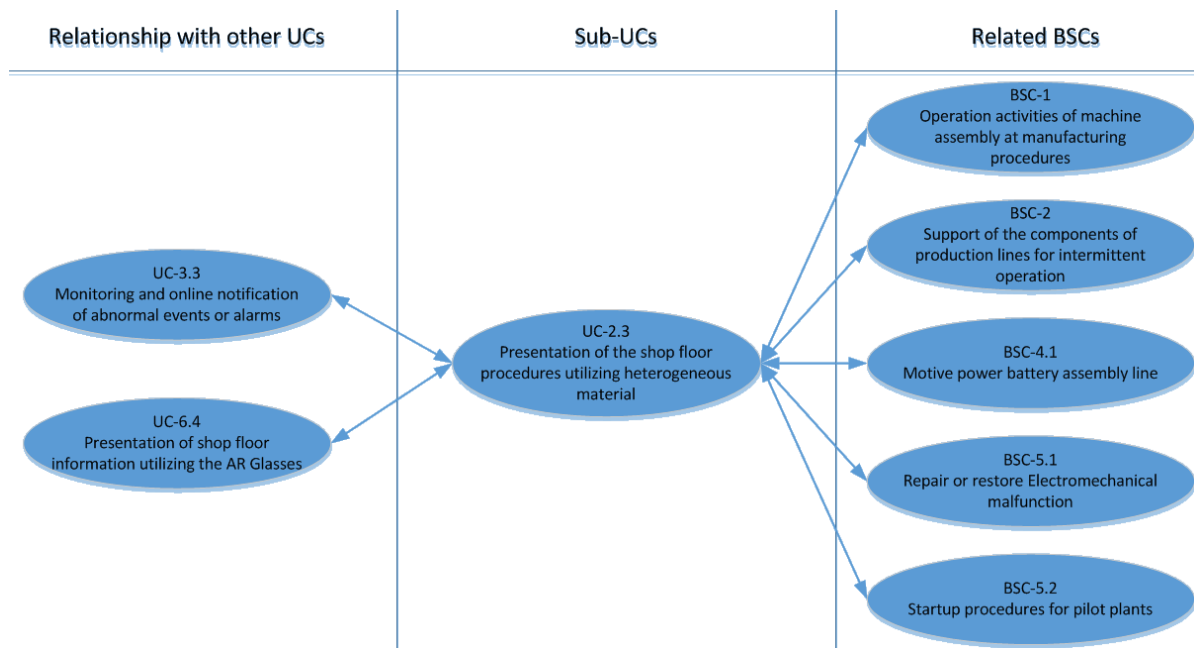


Figure 73 Relationship of UC-2.3 with other UCs and BSCs

6.5.3 UC-3 Dynamic utilization of augmented intelligence with intuitive information presentation

These Use Cases use the augmented intelligence interfaces and the thermal and depth cameras infrastructure to detect various incidents within the shop floor area. The target is mostly the safety of the workers inside the shop floor, which is a major issue for SatisFactory. The network of the installed cameras will monitor all day long the shop floor and try to detect incidents, minor or major, regarding the movement of the workers. Several kinds of notifications will be produced when the system detects a possible problem in order to alert workers and reduce shop floor related accidents.

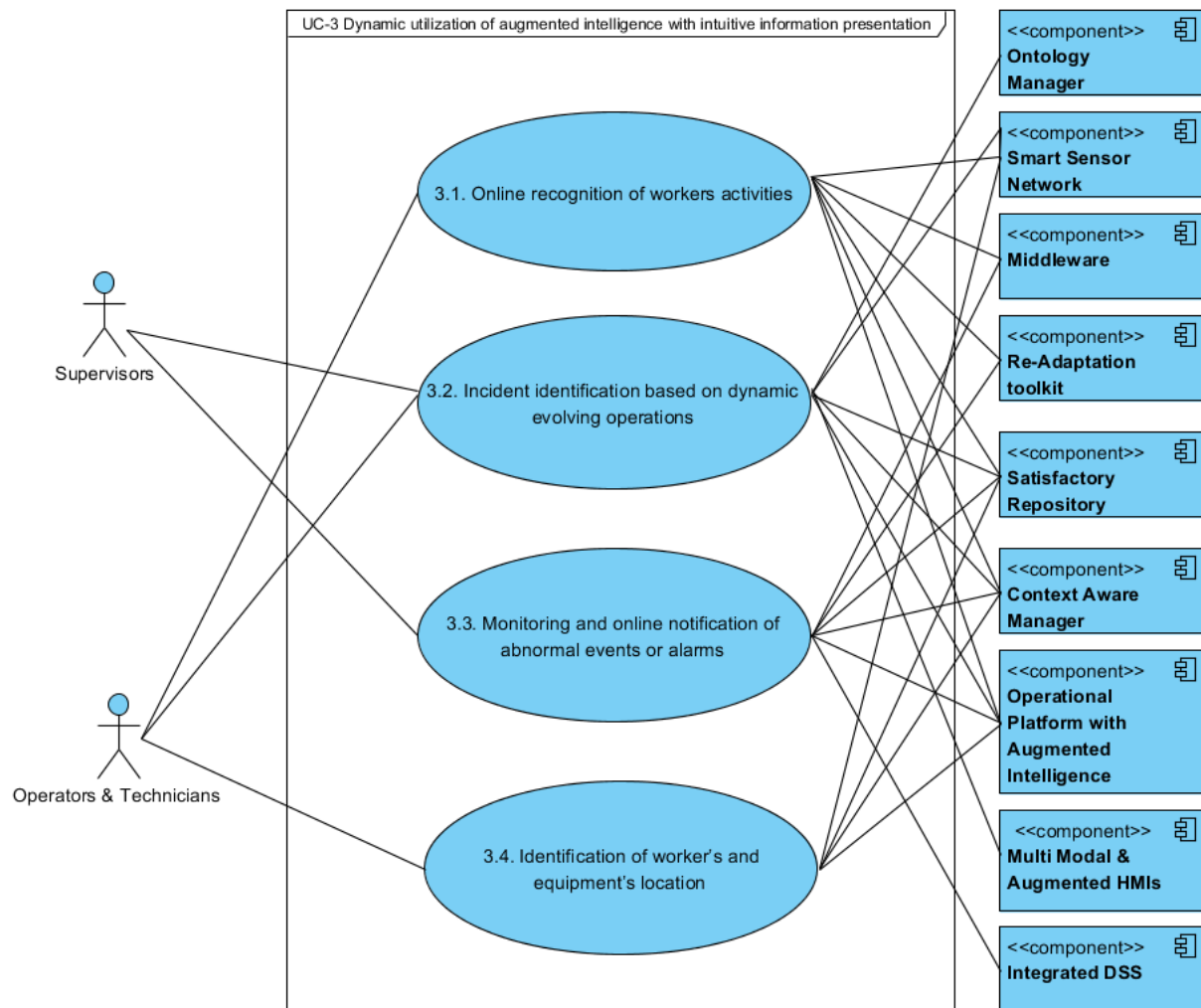


Figure 74 Analysis of UC-3

At the following table there is an analysis of the Use Case 3.1 according to the template that has been used.

Table 51 UC-3.1 Online recognition of workers activities

Use Case #	UC-3.1
Use Case Name	Online recognition of workers activities
Version/Author	v2 / CERTH/CPERI (CZ)
Brief Description	<p>This UC refers to the ability of the system to detect the activities performed by the analysis of the human behaviour at the shop floor area, using context aware information or gesture identification as the operations are evolving.</p> <p>The online recognition is performed using the capabilities of the Localization Manager in combination with the signals as acquire by the SSN and the AR devices.</p>

	A set of different activities at the shop floor will be tested in order to evaluate the response of the system. This UC targets mainly to the dynamically changing information as produced by the workers at specific and targeted working areas. The GCRM will not take place to recognised performed activities with this granularity. What will be available is the presence detection, status on operational progress, check report and safety gear recognition.
Pre-conditions	The workers perform activities at predetermined places at the shop floor where coverage by the appropriate components of the SSN is available. Thus, it's in the scope of this UC to monitor if a worker is wearing the required equipment for the desired area, cameras needs to be placed in the specific positions with specific view angles.
Post-conditions	Identification of the activity of interest which is performed at the shop floor
Goal (Successful End Condition)	The ultimate aim of this UC is to recognize the individual predetermined actions as performed by the actors on the basis of executing either a known procedure or a new one, and thus the generic identification is adequate for the successful completion of the UC.
Use Case Initiation	The status of the shop floor production lines and the time schedule indicates when this UC will be activated. The actors invoke the activities of this UC by performing the daily defined operations.
Involved Actors	Operators & Technicians
Architecture Components Involved	Context Aware Manager, Smart Sensor Network, SatisFactory Repository, Operational Platform with Augmented Intelligence, Middleware, Re-Adaptation toolkit
Related Business Scenario	BSC-1, BSC-2, BSC-3, BSC-4, BSC-5, BSC-6.1
Relationship with other Use Cases	UC-3.3, UC-3.4
Addressed requirements of the system	SAFA IDs: 140, 55, 41, 34, 24, 13
Restrictions	UWB radio connectivity can be affected by the harsh industrial environment. Availability of the UWB Anchor coordinates at the shop floor. The forbidden zones have to be pre-defined in the repository.

The next two figures present the connection of the Use case with the SatisFactory components and with the Business Scenarios and the other Use Cases.

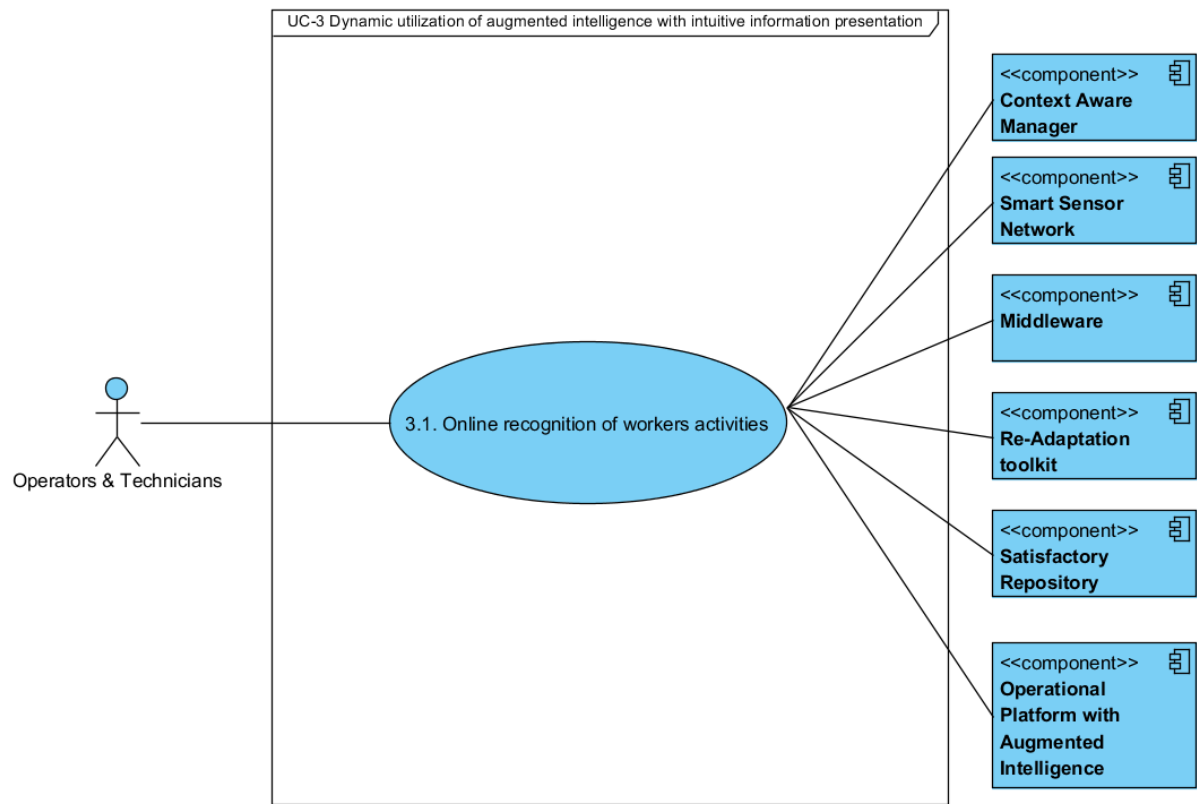


Figure 75 Analysis of UC-3.1

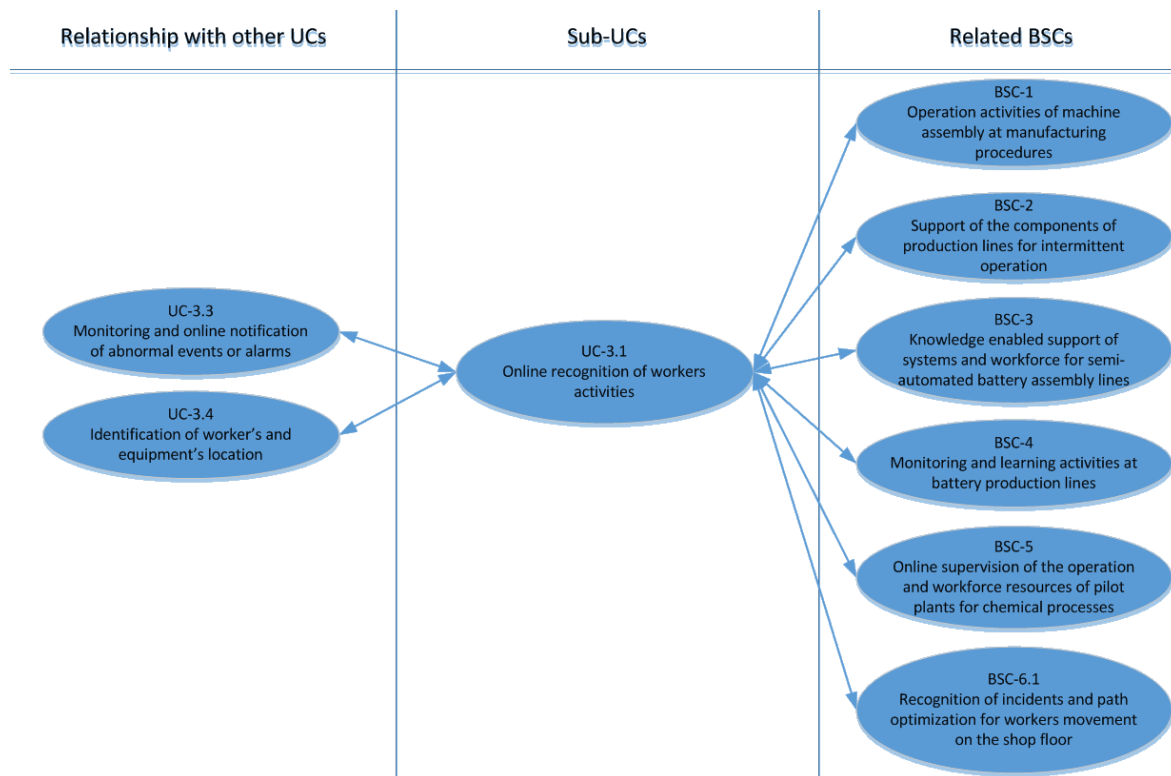


Figure 76 Relationship of UC-3.1 with other UCs and BSCs

At the following table there is an analysis of the Use Case 3.2 according to the template that has been used.

Table 52 UC-3.2 Incident identification based on dynamically evolving operations

Use Case #	UC-3.2
Use Case Name	Incident identification based on dynamically evolving operations
Version/Author	v2 / CERTH/CPERI (CZ)
Brief Description	This UC refers to the ability of the system to identify incidents at the shop floor based on the movement or location of the workers and objects using the Context Aware Manager component. It also includes incidents that could occur based on the data from the Comfort Sensor or from the Thermal Sensor Network. This UC is closely connected with UC-3.1 as it utilizes the information that is processed to identify possible incidents that occur at the designated areas where the workers are located. The Operational Platform in collaboration with the Ontology Manager analyse the shop floor data and determined whether an incident beyond the nominally defined operation has happened.
Pre-conditions	The Ontology Manager is responsible for the evaluation of the various events and the tagging of an event as an incident.

Post-conditions	The incidents are routed to the respective components to the corresponding information for the situation and their handling. The actors are informed by the Multi Model & Augmented HMLs while the incident is recorded to the SatisFactory Repository.
Goal (Successful End Condition)	The successful execution of this UC is verified by the identification of the incidents at the shop floors and the differentiation of them from the nominal operating procedures.
Use Case Initiation	The system monitors all involved actors and their activities. If these are deviating from the predefined ones, actions will be performed as this UC defines.
Involved Actors	Operators & Technicians
Architecture Components Involved	Smart Sensor Network, Ontology Manager, SatisFactory Repository, Operational Platform with Augmented Intelligence, Context Aware Manager
Related Business Scenario	BSC-6
Relationship with other Use Cases	Related to UC-3.3, UC-3.4
Addressed requirements of the system	SAFA IDs: 227, 140, 55, 41, 34, 27, 24, 13
Restrictions	Existence of guidelines to handle the triggering event. It will visualize only the supported and provided contents related to the incident. Availability of the UWB Anchor coordinates at the shop floor, The forbidden zones have to be pre-defined in the repository.

The next two figures present the connection of the Use case with the SatisFactory components and with the Business Scenarios and the other Use Cases.

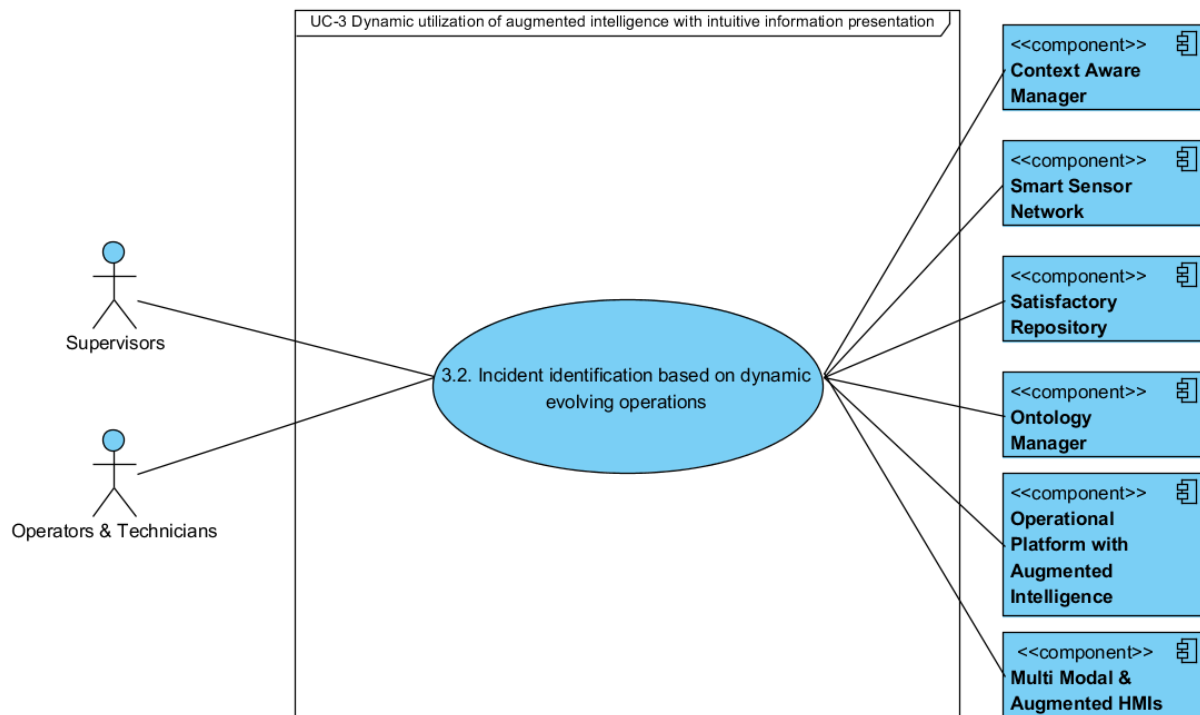


Figure 77 Analysis of UC-3.2

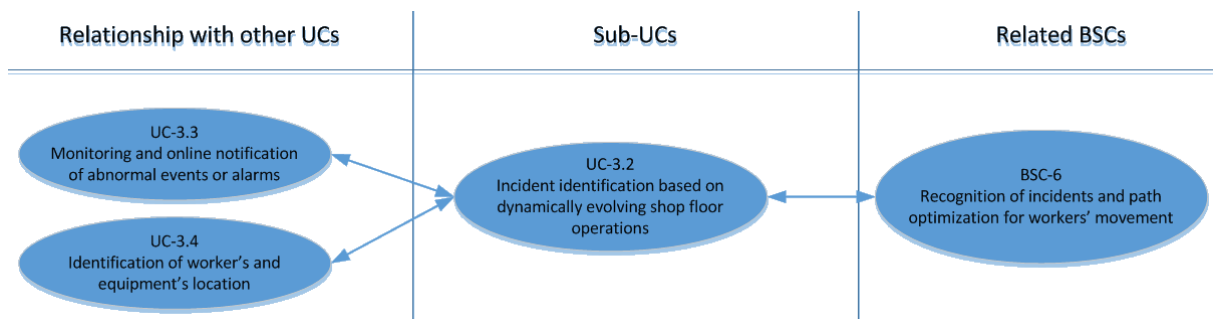


Figure 78 Relationship of UC-3.2 with other UCs and BSCs

At the following table there is an analysis of the Use Case 3.3 according to the template that has been used.

Table 53 UC-3.3 Monitoring and online notification of abnormal events or alarms

Use Case #	UC-3.3
Use Case Name	Monitoring and online notification of abnormal events or alarms
Version/Author	v2 / CERTH/CPERI (CZ)
Brief Description	This UC deals with the notification of abnormal events, situations and alarms to the involved actors across all levels of hierarchy at the shop floor. A suitable filtering is

	performed depending on the originating source and the severity/priority of the identified event or alarm. The actors are informed through the Multi Modal or Augmented HMIs while the integrated DSS provides the information necessary to complete the task, making a suggestion based on the shop floor's SOPs. The acknowledgment of the notification initiates the dispatching of the follow-up decision as dictated by the corresponding responsible component, e.g. when the event is related to maintenance activities the maintenance team is informed and proper notification for the course of events is automatically available through the Operational Platform.
Pre-conditions	Provision of all necessary data from the shop floor. Working environment and scheduling allows for all needed maintenance procedures.
Post-conditions	The abnormal malfunction must be verified outside of Integrated DSS and the notification must be fed to the DSS core. Existence of predicted response to the triggered event.
Goal (Successful End Condition)	The successful execution of this UC is verified by the notification of the involved actors about an abnormal event or an alarm originated by the operations performed at the shop floor or from the existing systems and are related to the status of the equipment that the actors are handling.
Use Case Initiation	The monitoring part of this UC is continuously running whereas the notification subpart is invoked when an event or alarms is identified.
Involved Actors	Supervisors, Managers & Engineers, Operators & Technicians
Architecture Components Involved	Integrated DSS, SatisFactory Repository, Context Aware Manager, Middleware (Event Manager), Re-Adaptation toolkit, Operational Platform with Augmented Intelligence
Related Business Scenario	BSC-2.1, BSC-5.1, BSC-4.2, BSC-6
Relationship with other Use Cases	UC-3.2 (incidents), UC-1.3 (shop floor data), UC-4.3 (monitoring)
Addressed requirements of the system	SAFA IDs: 229, 222, 115, 76, 67, 66, 55, 41, 24, 13
Restrictions	Existence of guidelines to handle the triggering event. There should not be materials that would probably lead to abnormal operation of the cameras (areas with a lot glasses, mirrors, and other reflection materials).

The next two figures present the connection of the Use case with the SatisFactory components and with the Business Scenarios and the other Use Cases.

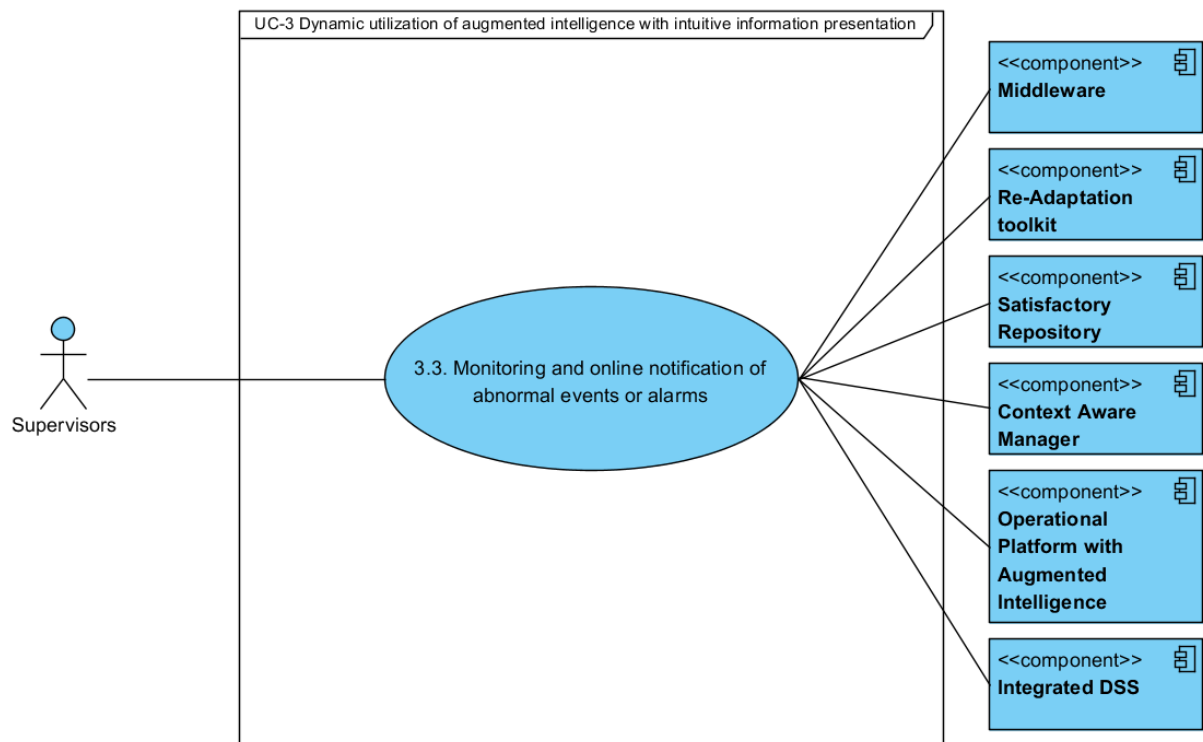


Figure 79 Analysis of UC-3.3

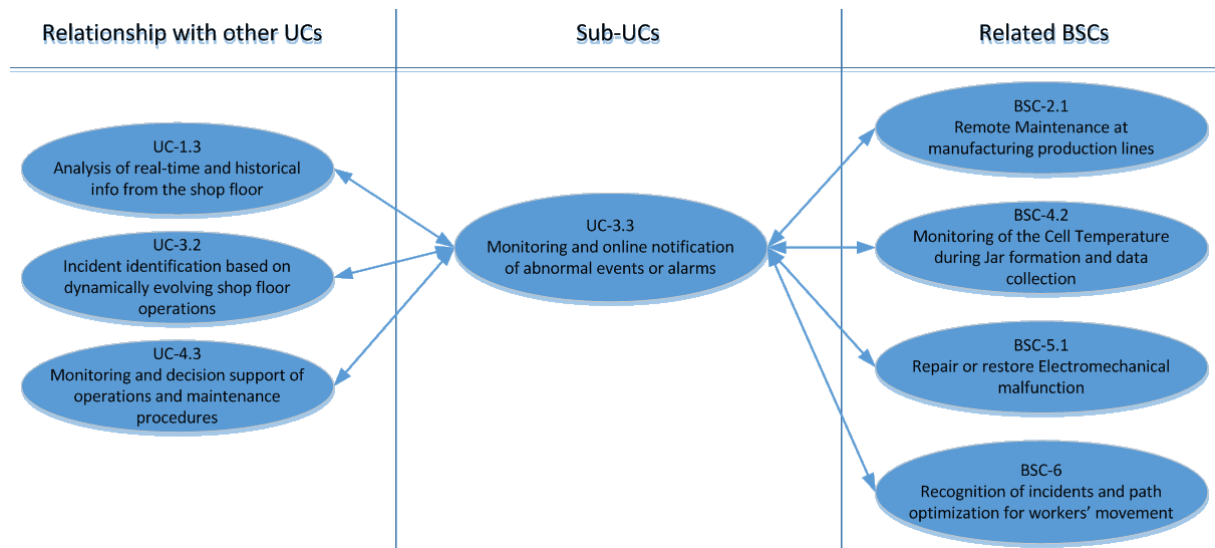


Figure 80 Relationship of UC-3.3 with other UCs and BSCs

At the following table there is an analysis of the Use Case 3.4 according to the template that has been used.

Table 54 UC-3.4 Identification of worker's and equipment's location

Use Case #	UC-3.4
Use Case Name	Identification of worker's and equipment's location
Version/Author	v2 / CERTH/CPERI (CZ)
Brief Description	This UC describes the functions of the Satisfactory system that are responsible for the identification of worker's and equipment's location at the shop floor. The Localization manager uses the information from the SSN and in conjunction with the information from the repository and the knowledge base of the system, provides the necessary information to the components of the architecture that handle location related activities. This UC deals with the analysis of the SSN data and the translation of them into useful information as the operation activities and maintenance procedures are dynamically evolving.
Pre-conditions	Shop floor layout is available and stored at the Repository (MAP). The location of all the equipment is known as the UWB anchors.
Post-conditions	The location of the worker is available to be used by the integrated DSS and the Operational Platform.
Goal (Successful End Condition)	The main goal of this UC is to locate the position of the actors with respect to the other equipment that exist at the shop floors and to pin point their location at the shop floor area.
Use Case Initiation	This UC is initiated when the SSN receives data from the component that are responsible for detecting movement, such as the Cameras and sensors from the Dependable Network Infrastructure
Involved Actors	Operators & Technicians
Architecture Components Involved	Smart Sensor Network, Satisfactory Repository, Context Aware Manager, Operational Platform with Augmented Intelligence
Related Business Scenario	BSC-5.1, BSC-5.2, BSC-6.1
Relationship with other Use Cases	UC-1.3 (shop floor data), UC-3.2 (info for incidents) , UC-3.1 (worker's activities), UC-3.3 (info for events)
Addressed requirements of the system	SAFA IDs: 228, 223, 41, 13
Restrictions	There should not be materials that would probably lead to abnormal operation of the cameras (areas with a lot glasses, mirrors, and other reflection materials). UWB radio connectivity can be affected by the harsh industrial environment. Availability of the UWB Anchor coordinates at the shop floor.

The next two figures present the connection of the Use case with the SatisFactory components and with the Business Scenarios and the other Use Cases.

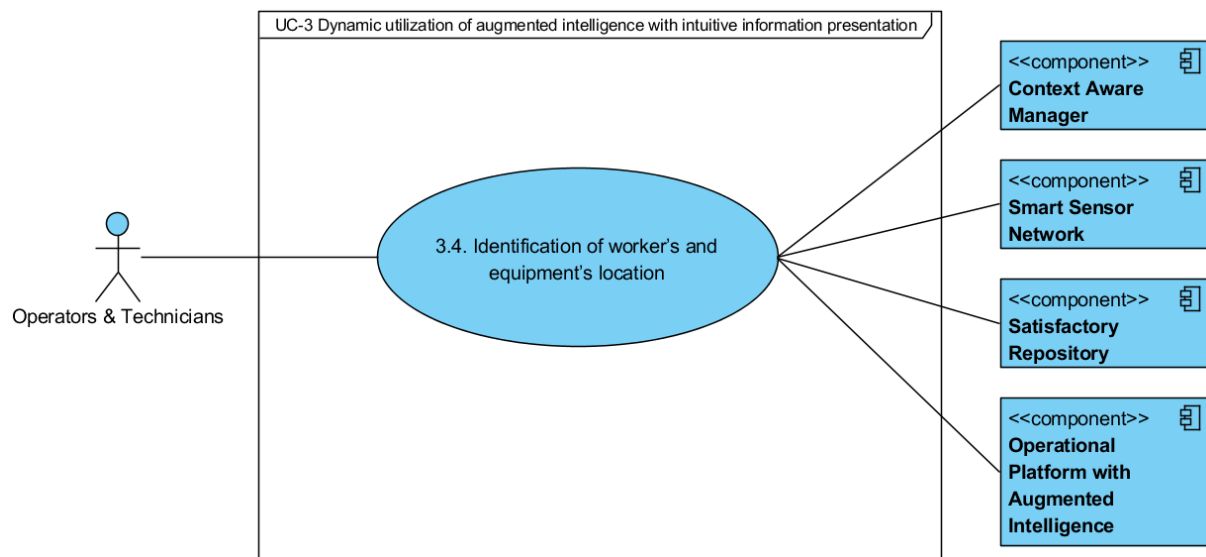


Figure 81 Analysis of UC-3.4

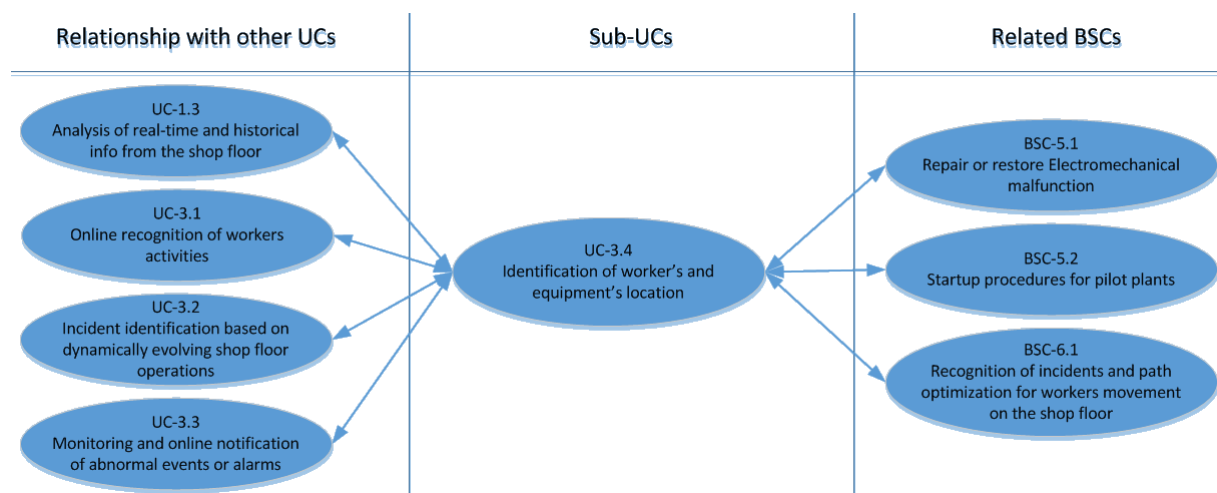


Figure 82 Relationship of UC-3.4 with other UCs and BSCs

6.5.4 UC-4 Intelligent decision support and maintenance for increased flexibility

The following list of Use Cases refers to maintenance and decision support procedures. The maintenance of the machinery is an important issue for every maintenance manager and it is rather complicated. A maintenance plan which will handle the availability of the workers and the necessary resources will increase flexibility of the technical team and decrease the downtime of the shop floor operation.

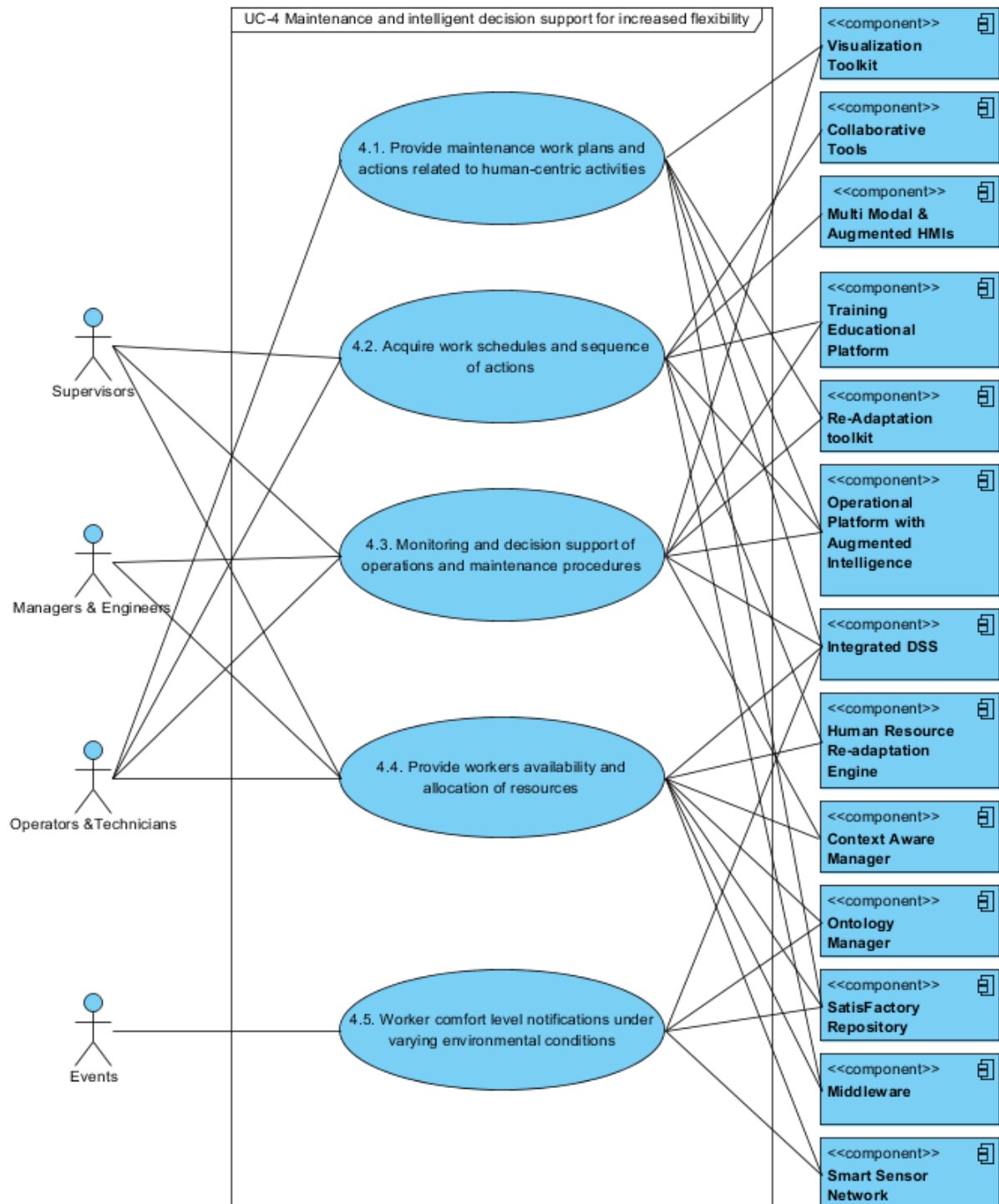


Figure 83 Analysis of UC-4

At the following table there is an analysis of the Use Case 4.1 according to the template that has been used.

Table 55 UC-4.1 Provide maintenance work plans and actions related to human-centric activities

Use Case #	UC-4.1
Use Case Name	Provide maintenance work plans and actions related to human-centric activities
Version/Author	v2 / CETH/CPERI (CZ)
Brief Description	<p>This UC refers to the usage of the Integrated Decision Support System and its subcomponents at the shop floor operations. As the operations involve numerous decisions making situations this UC invokes the appropriate component depending on the activities or the operations to be performed at the shop floor.</p> <p>The operators and technicians have access to their work plans and actions according to the workload distribution and the status of the scheduled activities. Each technician receives its maintenance related work plan and each operator receives its work assignments through the Multi Modal HMI's.</p>
Pre-conditions	<p>Formalized maintenance operating procedures to solve the fault should be present. Any resources (images, 3d models) useful to describe the procedures themselves. Clear and effective messages (images, text, icons) have to be generated at runtime by external specialized components and sent to AR Tools that will present these contents in the Multi Modal HMIs.</p> <p>Provision of all necessary data from the shop floors. Working environment and scheduling allows for all needed maintenance procedures.</p> <p>In case the suggested maintenance activities cannot be performed for some reason, information is needed to prioritize the involved activities.</p>
Post-conditions	It will present the maintenance and the procedures that need to be followed to the involved actor by a different view of detail depending on the role of the actor.
Goal (Successful End Condition)	The involved actors are informed about the requested course of actions or procedures. Gamify aspects of maintenance operation.
Use Case Initiation	The UC is initiated when an actor request for information related to maintenance or operation activities according to the daily work plan.
Involved Actors	Operators & Technicians
Architecture Components Involved	Operational Platform with Augmented Intelligence, Visualization toolkit, Integrated DSS, SatisFactory Repository, Re-Adaptation toolkit
Related Business Scenario	BSC-2, BSC-3, BSC-5
Relationship with other Use Cases	UC-4.2 (acquire work schedule and sequence of actions)
Addressed requirements of the system	SAFA IDs: 229, 223, 187, 186, 184, 178, 149, 148, 137, 136, 108, 41, 37, 33, 32, 18
Restrictions	-

The next two figures present the connection of the Use case with the SatisFactory components and with the Business Scenarios and the other Use Cases.

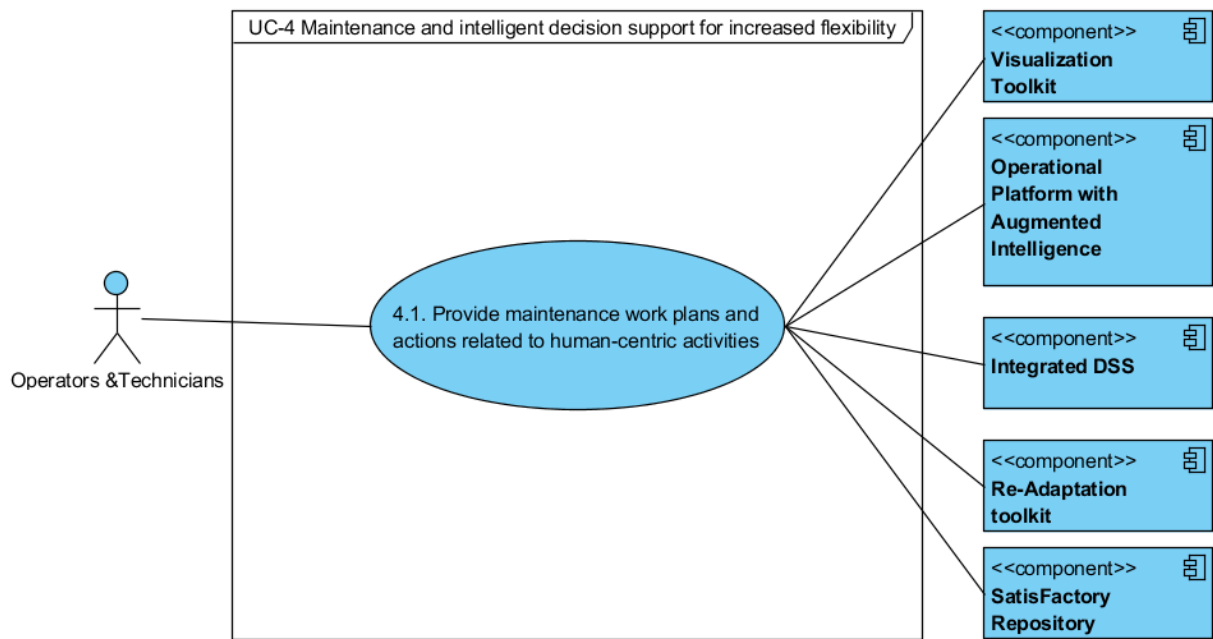


Figure 84 Analysis of UC-4.1

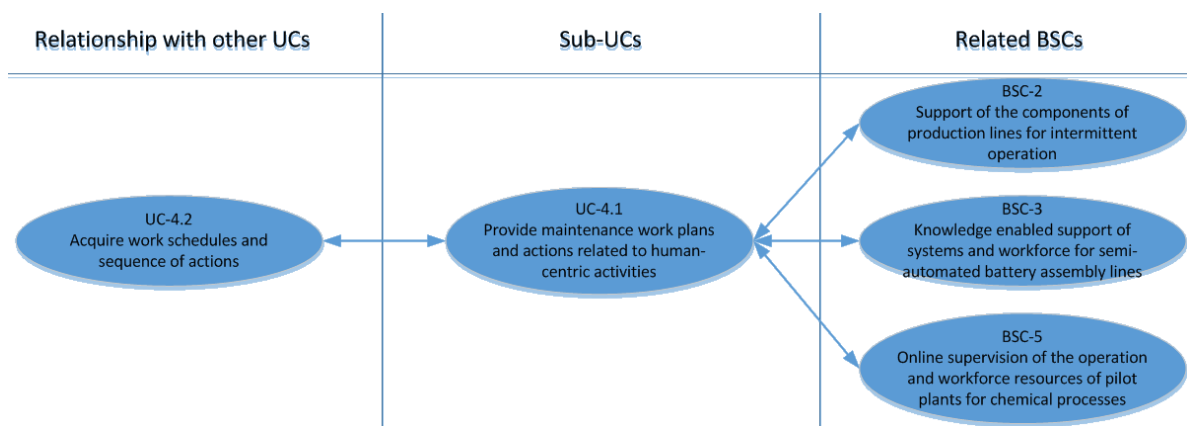


Figure 85 Relationship of UC-4.1 with other UCs and BSCs

At the following table there is an analysis of the Use Case 4.2 according to the template that has been used.

Table 56 UC-4.2 Acquire work schedules and sequence of actions

Use Case #	UC-4.2
Use Case Name	Acquire work schedules and sequence of actions
Version/Author	v2 / CERTH/CPERI (CZ)
Brief Description	<p>This UC refers to the functionalities of the system that are responsible the determination of which work schedules or sequence of actions will be provided to the worker that initiated the request through the respective components. This UC handles the requests originated from the Multi-modal and Augmented HMIs that use the Operational platform, the Collaboration tools or the Educational platform.</p> <p>The UC will distribute information on which schedule workers have to work for the day (daily changes) and to make this information easily and clearly accessible</p>
Pre-conditions	Provision of all necessary data from the shop floors. Working environment and scheduling allows for all needed maintenance procedures.
Post-conditions	<p>Work schedules and sequence of actions are available</p> <p>Each worker knows about his/her schedule for the day.</p> <p>Workers have access to their daily schedule in an intuitive and easy to use way</p>
Goal (Successful End Condition)	<p>The Operational Platform receives the necessary data for the procedures from the other component in order to be able to send the appropriate information to the originating source that invoked the UC.</p> <p>Inform workers about schedule for the day</p>
Use Case Initiation	The UC is initiated when an actor request for information related to work schedules and sequence of actions.
Involved Actors	Supervisors, Operators & Technicians
Architecture Components Involved	Operational Platform with Augmented Intelligence, Collaborative tools, Training educational platform, Multi Modal & Augmented HMIs, Middleware (Middleware-Core), Human Resource Re-Adaptation Engine
Related Business Scenario	BSC-1,BSC-2, BSC-3, BSC-4, BSC-5
Relationship with other Use Cases	Related to UC-2.3, UC-4.1
Addressed requirements of the system	SAFA IDs: 223, 176, 171, 149, 148, 137, 134, 133, 108, 41
Restrictions	-

The next two figures present the connection of the Use case with the Satisfactory components and with the Business Scenarios and the other Use Cases.

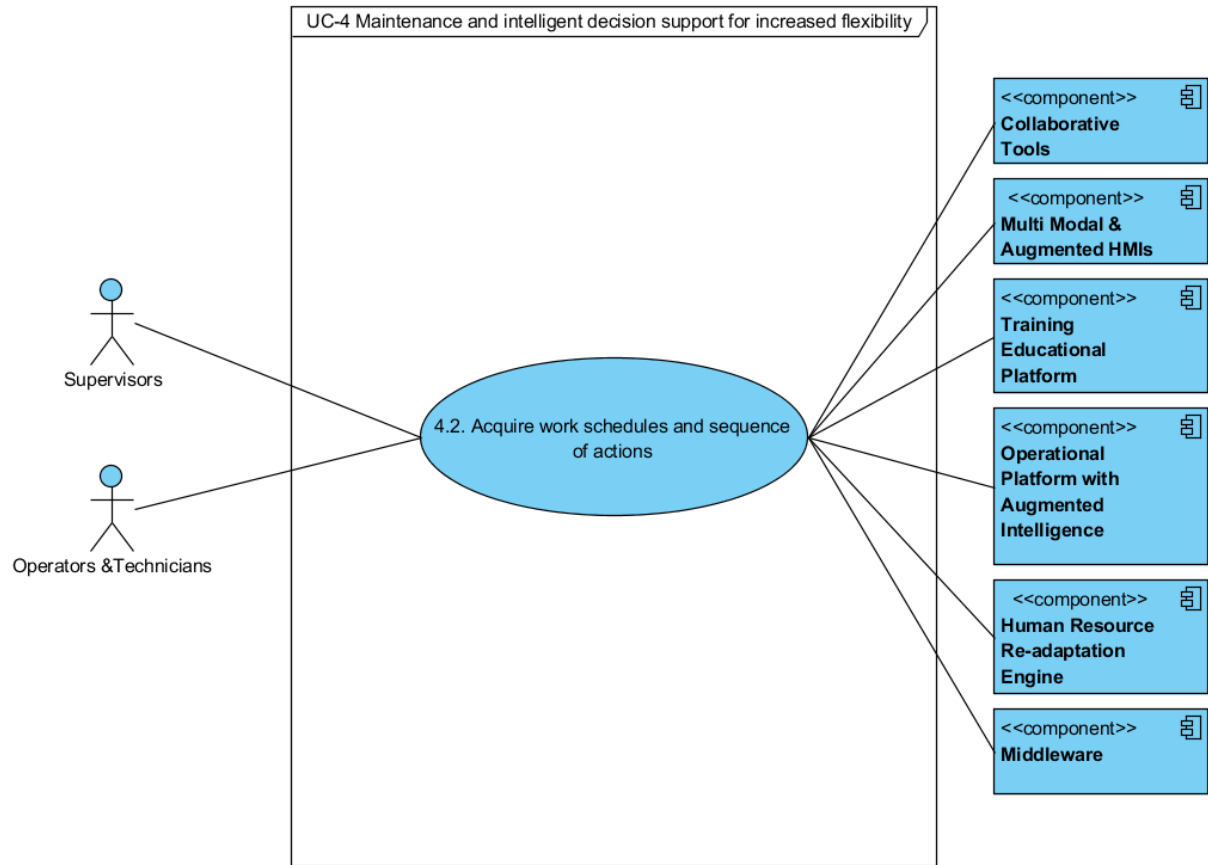


Figure 86 Analysis of UC-4.2

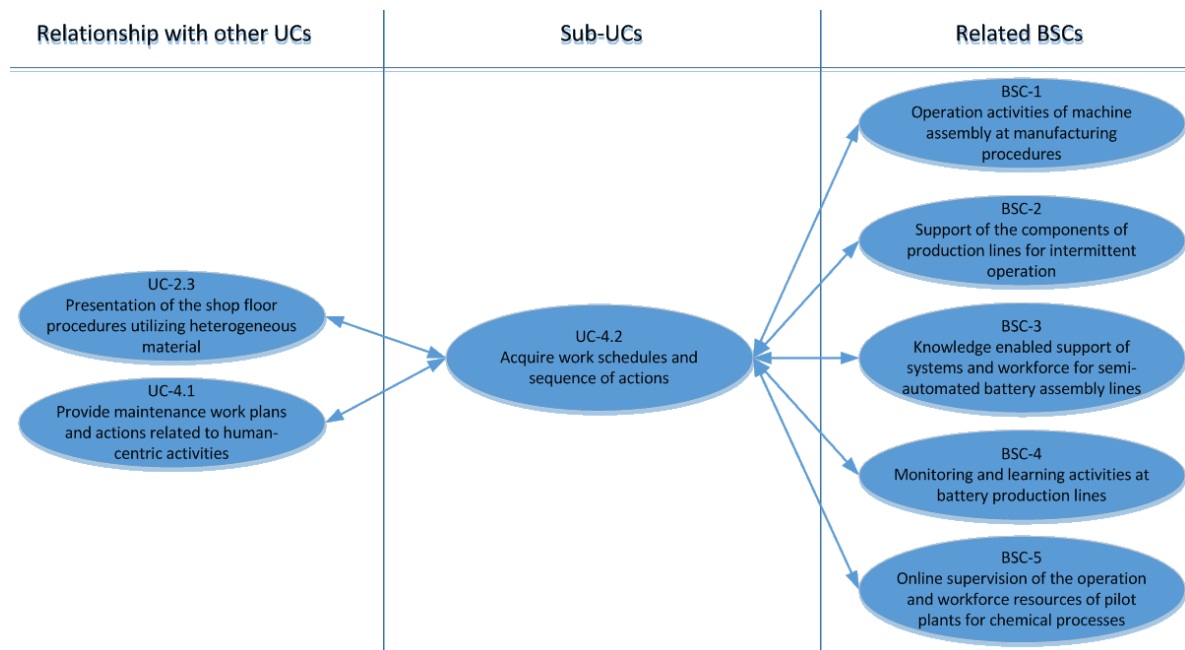


Figure 87 Relationship of UC-4.2 with other UCs and BSCs

At the following table there is an analysis of the Use Case 4.3 according to the template that has been used.

Table 57 UC-4.3 Monitoring and decision support of operations and maintenance procedures

Use Case #	UC-4.3
Use Case Name	Monitoring and decision support of operations and maintenance procedures
Version/Author	v2 / CERTH/CPERI (CZ)
Brief Description	<p>This UC is responsible for the monitoring of the operations and the maintenance procedures at the shop floor using the SSN. The decision support functions are provided upon request by the integrated DSS through the Multi Modal or Augmented HMIs. The semantically-enhanced functionalities of the Re-adaptation toolkit assist the decision making process related to the evolving production procedures. This UC is the main point of communication of the integrated DSS and the other components at the services layer of the SatisFactory architecture.</p> <p>The AR interface provide to the actors an overview of their action during their shift as well as real time information related to changes regarding their work such a modification to the work order due to limited raw materials or due to delays caused by unplanned maintenance activities.</p>
Pre-conditions	Provision of all necessary data from the shop floors. Working environment and scheduling allows for all needed maintenance procedures.

Post-conditions	Generation of suggested actions to actors request to perform predefined procedures at the shop floor. The decisions are filtered depending on the role of the actor and the status of the activities that take place at the shop floor (training or nominal operation of production lines and processes)
Goal (Successful End Condition)	The successful execution of this UC is verified by the notification of the involved actors about an abnormal event or an alarm originated by the operations performed at the shop floor or from the existing systems and are related to the status of the equipment that the actors are handling.
Use Case Initiation	The monitoring part of this UC is continuously running whereas the decision support subpart is invoked when an actor had requested assistance or it is requested by the course of event as described the Operating Procedures. This UC is initiated by the actors that perform various procedures at the shop floor after they have received their work plan and time schedule of their activities.
Involved Actors	Supervisors, Operators & Technicians
Architecture Components Involved	Integrated DSS, Context Aware Manager, Training educational platform, Visualization toolkit, Operational Platform with Augmented Intelligence, Readaptation Toolkit
Related Business Scenario	BSC-1, BSC-2, BSC-3, BSC-4, BSC-5
Relationship with other Use Cases	UC-4.1, UC-2.3, UC-1.3
Addressed requirements of the system	SAFA IDs: 222, 115, 108, 55, 41, 24
Restrictions	-

The next two figures present the connection of the Use case with the SatisFactory components and with the Business Scenarios and the other Use Cases.

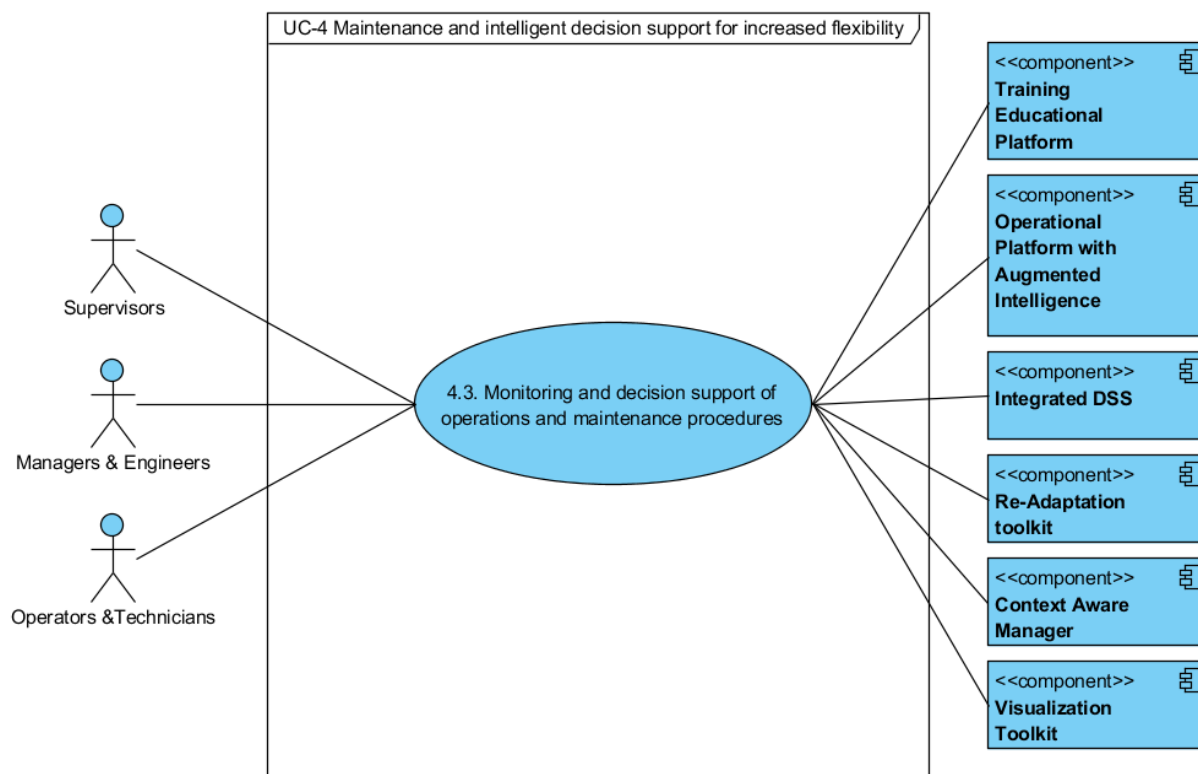


Figure 88 Analysis of UC-4.3

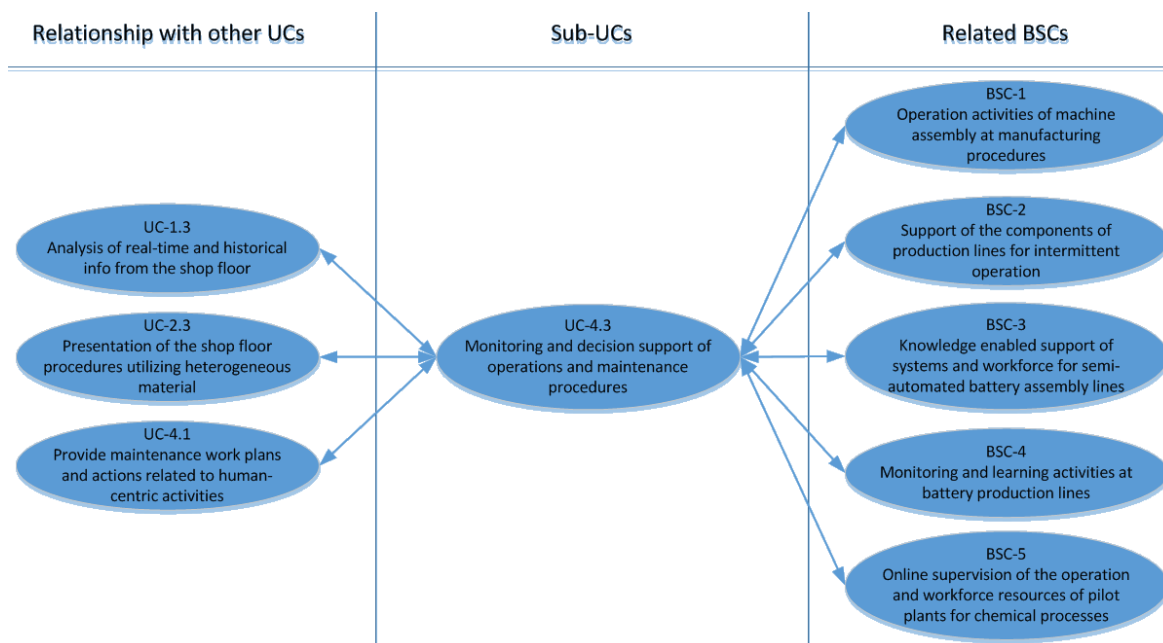


Figure 89 Relationship of UC-4.3 with other UCs and BSCs

At the following table there is an analysis of the Use Case 4.4 according to the template that has been used.

Table 58 UC-4.4 Provide workers availability and allocation of resources

Use Case #	UC-4.4
Use Case Name	Provide workers availability and allocation of resources
Version/Author	v2 / CETH/CPERI (CZ)
Brief Description	This UC is responsible for the provision of information related to the allocation of the human resources and the workload balance by utilizing online data from the monitoring and online activities. The availability of the resources and the flexibility of their reallocation are considered using a combination of online data and stored information related to the standard or emergency operating procedures that are explicitly defined for each shop floor and activity within the shop floor. Furthermore, the availability depends on multi-variable criteria and in conjunction with the daily time schedule. Thus, this UC demonstrates the capability of the system to provide flexible workload allocation by examining numerous potential scenarios and production requirements.
Pre-conditions	Each operators and technician has enabled the procedures for logging of the activities. More specifically the workplace and type of activity in combination with time details should be logged into the dynamic element of the Repository.
Post-conditions	Generation of reports or views for the involved actors concerning the allocation of resources and the dynamic allocation or reallocation of actors to the shop floor activities.
Goal (Successful End Condition)	The main goal of this UC is the successful generation of the allocation of the resources that are needed to perform part of the activities and most importantly to determine the availability of the involved actors in term of their time slot allocations to specific areas or procedures at the shop floor or the production lines.
Use Case Initiation	The operators and technicians check for their allocated time slots and place to work and the supervisors and managers request to see the availability of their operators and technicians in order to make the appropriate planning and programming of future activities or respond to unplanned events.
Involved Actors	Supervisors, Managers & Technicians, Operators & Technicians
Architecture Components Involved	Integrated DSS, Ontology Manager, Smart Sensor Network, SatisFactory Repository, Human Resource Re-Adaptation Engine, Middleware, Context Aware Manager
Related Business Scenario	BSC-2, BSC-3, BSC-5.1, BSC-5.3
Relationship with other Use Cases	UC-4.3, UC-4.1
Addressed requirements of the system	SAFA IDs: 229, 222, 149, 148, 137, 134, 133, 107, 41, 24
Restrictions	-

The next two figures present the connection of the Use case with the SatisFactory components and with the Business Scenarios and the other Use Cases.

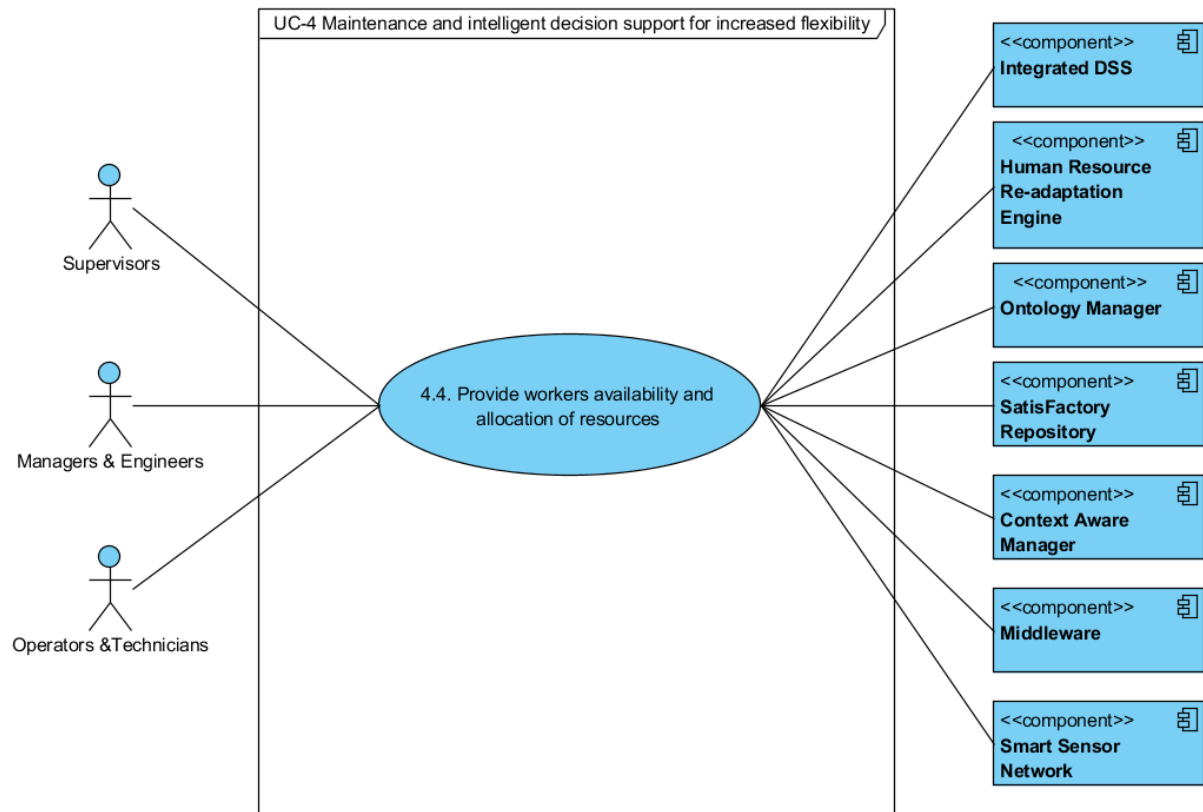


Figure 90 Analysis of UC-4.4

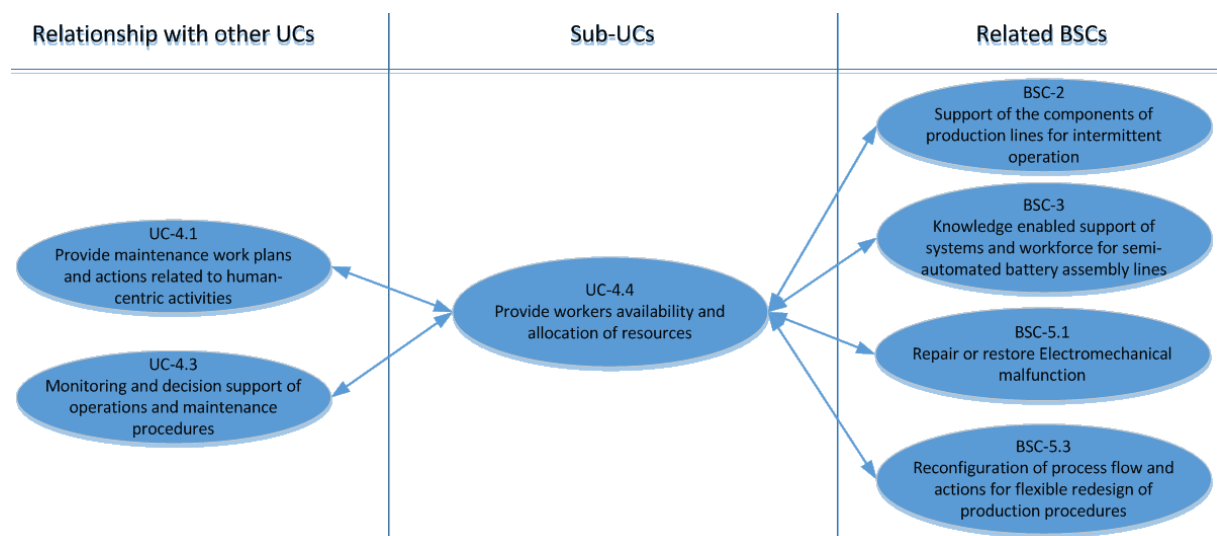


Figure 91 Relationship of UC-4.4 with other UCs and BSCs

At the following table there is an analysis of the Use Case 4.5 according to the template that has been used.

Use Case #	UC-4.5
Use Case Name	Worker comfort level notifications under varying environmental conditions
Version/Author	v1 / CERTH/ITI
Brief Description	This UC is responsible for providing environmental measurements related to the comfort level of workers or trigger events in case of extreme conditions. A number of wireless nodes with sensors are utilized to periodically provide environmental parameter measurements like temperature, humidity, light and noise levels. Air quality measurements can also be added. The information available can be utilized to effectively categorize each area as comfortable or not for long term worker occupancy or even initiate corrective actions to restore comfortable levels and prevent accidents. In areas where higher risk of extreme conditions exists, a node can be event triggered provided that it is not battery operated.
Pre-conditions	Each battery operated sensor has enough battery to perform measurements. Each sensor is exposed to the parameters measured.
Post-conditions	The SatisFactory repository is updated with the last measurements reported by the sensor.
Goal (Successful End Condition)	Each controlled area is categorized based on statistical analysis of past measurements. Corrective actions have led to restored comfort and/or safety at an area.
Use Case Initiation	A sensor node will measure and report the levels of the parameters measured when the configured period of time since the previous report passes. Mains powered sensor nodes can be event triggered and will report extreme conditions in real time.
Involved Actors	Supervisors, Managers & Technicians, Operators & Technicians
Architecture Components Involved	Integrated DSS, Ontology Manager, Smart Sensor Network, SatisFactory Repository
Related Business Scenario	BSC-5
Relationship with other Use Cases	UC-1
Addressed requirements of the system	SAFA IDs: 172, 135, 13
Restrictions	Event triggered nodes should be mains powered.

The next two figures present the connection of the Use case with the SatisFactory components and with the Business Scenarios and the other Use Cases.

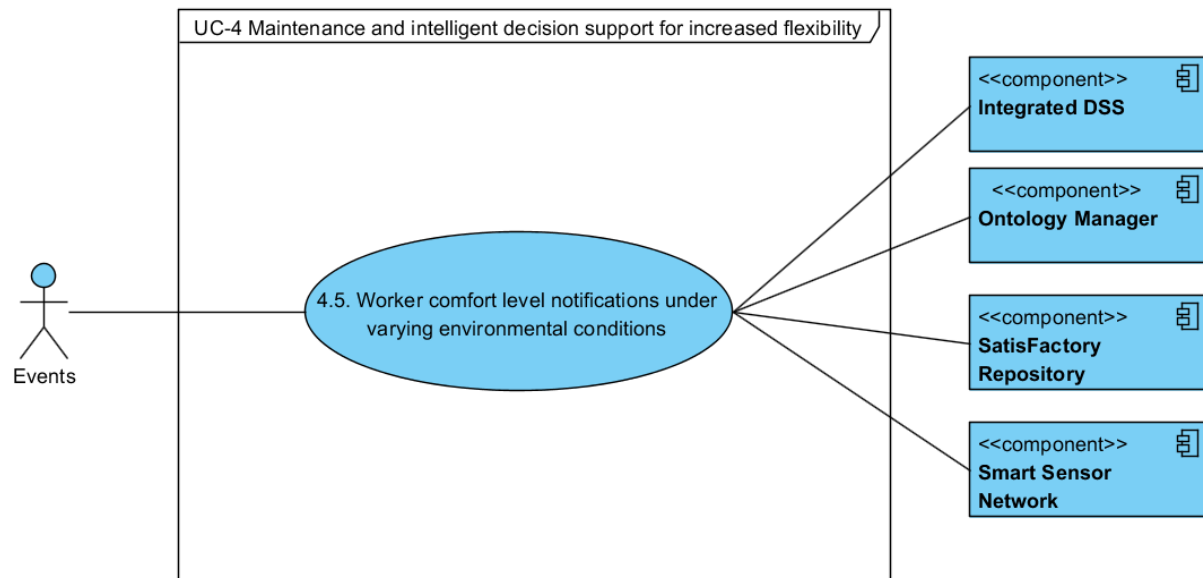


Figure 92 Analysis of UC-4.5

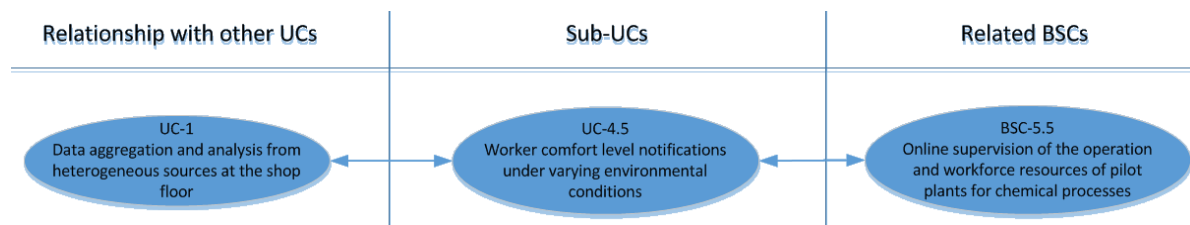


Figure 93 Relationship of UC-4.5 with other UCs and BSCs

6.5.5 UC-5 Collaboration and social interaction for increased workers' engagement

This list of Use Cases targets mostly to increase the satisfaction of the works. The Fun Content platform will make the breaks of the workers more interesting and help them to enjoy and to have a pleasant time. The platform for suggestion will help the workers to interact with the system and give suggestions for improvement if it is needed.

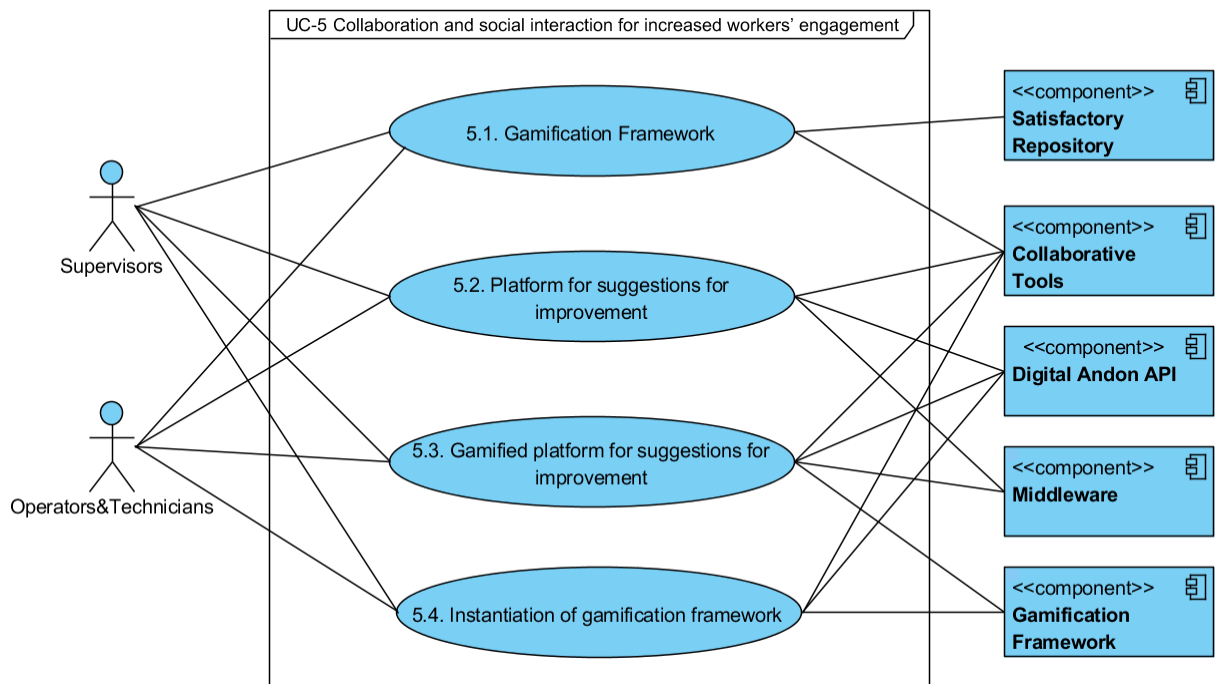


Figure 94 Analysis of UC-5

At the following table there is an analysis of the Use Case 5.1 according to the template that has been used.

Table 59 UC-5.1 Gamification framework

Use Case #	UC-5.1
Use Case Name	Gamification framework
Version/Author	v2 / FIT
Brief Description	<p>The Gamification Framework is a framework for applying gamification in various aspects of SatisFactory. Different external systems can use the APIs provided by this framework to become a part of the whole gamification environment at the factory.</p> <p>Each game is created by either the external systems or the management. Each game can consist of various tasks. Each task is of certain points. Workers can take part in this game either individually or in the form of teams. Upon performing a specific task, the external system informs the Gamification Framework about the worker who performed the task and the task he just performed. That worker or his team, depending on the game type, is awarded with the respective points. These points are then accumulated into a grand total which shows whether the workers have surpassed their previous score or not. The collective information is displayed on the Digital Display Screen. The workers can also view their personal scores and</p>

	achievements via a mobile app.
Pre-conditions	The SatisFactory Applications are integrated to the Gamification framework
Post-conditions	All Applications contribute to the overall scoring for every participant based on the applications rules
Goal (Successful End Condition)	Gamification motivate users to perform better in the domain of every SatisFactory Application
Use Case Initiation	An application initiates connection with the framework
Involved Actors	Supervisors, Operators & Technicians
Architecture Components Involved	SatisFactory Repository, Collaborative Tools
Related Business Scenario	BSC1, BSC2, BSC3, BSC4, BSC5
Relationship with other Use Cases	UC-5
Addressed requirements of the system	SAFA IDs: 221, 220, 218, 217, 215, 206, 205, 204, 174, 131, 120, 62, 59
Restrictions	Safety: All actors involved in the use case should be compliant with the safety requirements and the instructions given by the safety manager.

The next two figures present the connection of the Use case with the SatisFactory components and with the Business Scenarios and the other Use Cases.

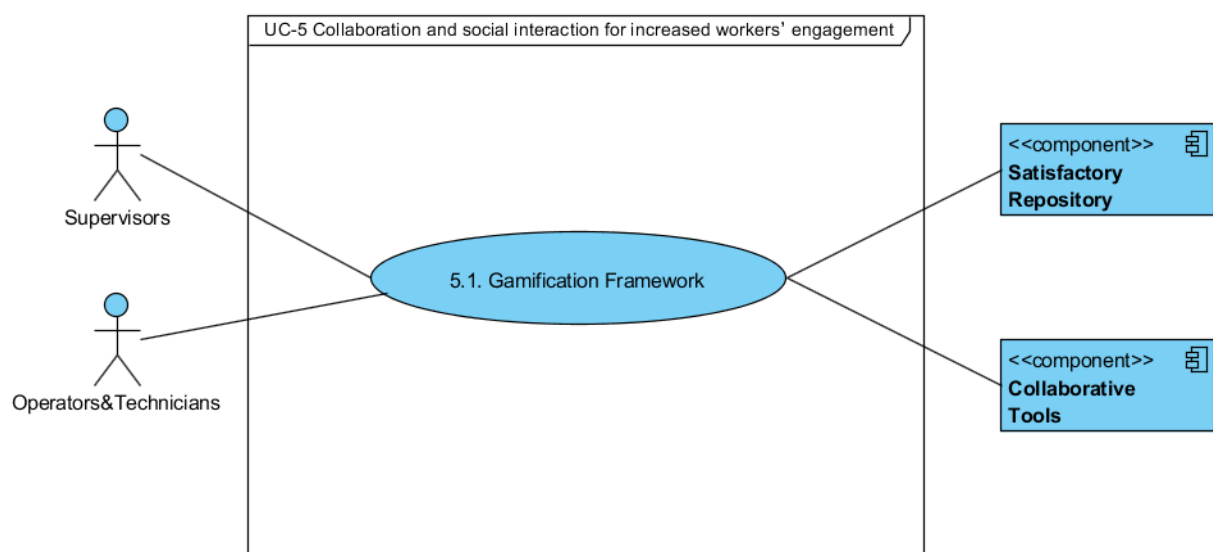


Figure 95 Analysis of UC-5.1

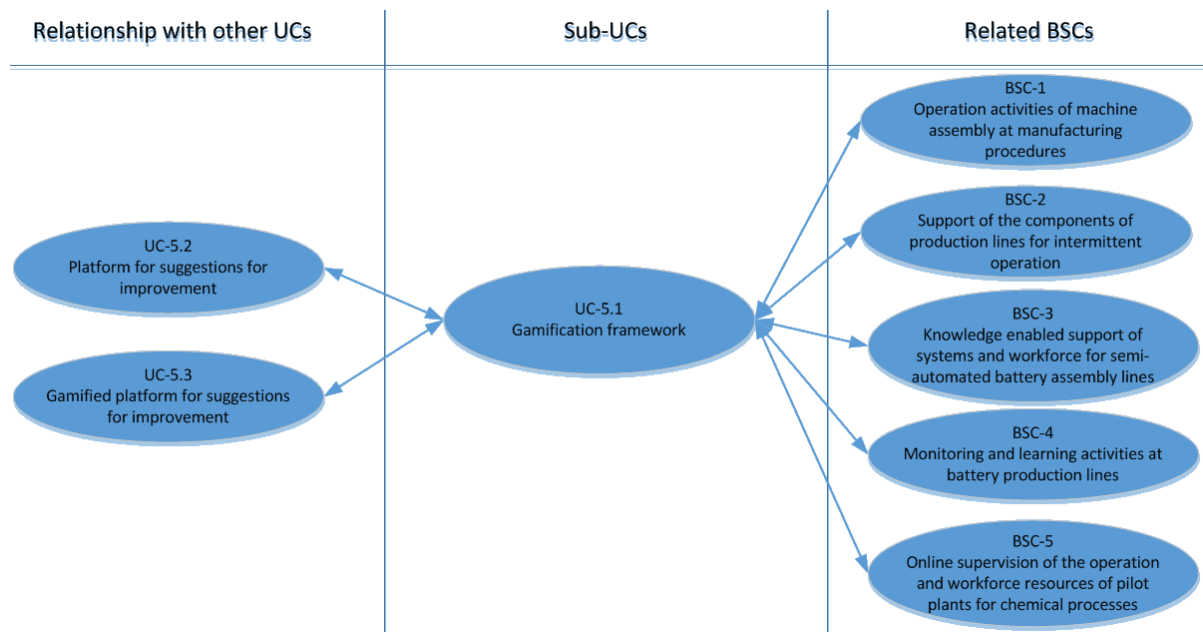


Figure 96 Relationship of UC-5.1 with other UCs and BSCs

At the following table there is an analysis of the Use Case 5.2 according to the template that has been used.

Table 60 UC-5.2 Platform for suggestions for improvement

Use Case #	UC-5.2
Use Case Name	Platform for suggestions for improvement
Version/Author	v2 / FIT
Brief Description	<p>This UC is related to the operation of a web-based tool, where suggestions for improvement can be entered. The GUI is reduced to the minimum requested information and in general optimized with regard to usability so that suggestions can be entered quickly during short idle times. The tool is accessible from intra-factory Wi-Fi so that it is made sure that only factory workers can access it.</p> <p>The involved actors access the tool from their office workplace using an adapted interface. For each suggestion, they need to enter whether it was applied, whether it was applied with modification or whether it was not applied. In the latter case, the reason for rejection is mandatory. This information is fed back to the worker who entered the suggestion. The main flow of action is:</p> <ul style="list-style-type: none"> • Identification of a potential for improvement • Provision of a suggestion • Deciding on a suggestion • Provision of feedback <p>A worker has an idea how to overcome a problem in the daily work process. It could also be that the worker firstly identified a problem and then also found a solution for it. He decides to make a suggestion for improvement.</p>

	<p>At a small idle time, the worker grabs his smartphone and browses to the suggestions for improvement platform. He quickly fills out the few mandatory forms in order to provide the suggestion to the platform.</p> <p>A manager opens the suggestions platform from his office computer and gets presented a list of suggestions that is relevant to him (we need to investigate how to find out for which decide a particular suggestion is relevant). At another idle time, the worker again logs in into the suggestions for improvement platform. He has a new notification telling him that his suggestion could not be applied due to the technical reasons.</p>
Pre-conditions	Not Applicable
Post-conditions	<p>Minimal Guarantees: Logging of suggestions for improvement</p> <p>Success Guarantees: A suggestion for improvement reaches the person who can decide on it. The worker gets feedback whether his suggestion was applied and, in case of rejection, the reason for the rejection.</p>
Goal (Successful End Condition)	Improve the process of workers make suggestions for process improvements
Use Case Initiation	Worker identifies potential for improvement and decides to make a suggestion
Involved Actors	Supervisors, Operators & Technicians
Architecture Components Involved	Collaborative Tools, Digital Andon API, Middleware
Related Business Scenario	BSC-1, BSC-3.1
Relationship with other Use Cases	UC-5.2
Addressed requirements of the system	SAFA IDs: 211, 208, 207, 203, 202, 200, 198, 197, 193, 192, 146, 136, 105, 41, 17, 4
Restrictions	Safety: All actors involved in the use case should be compliant with the safety requirements and the instructions given by the safety manager.

The next two figures present the connection of the Use case with the SatisFactory components and with the Business Scenarios and the other Use Cases.

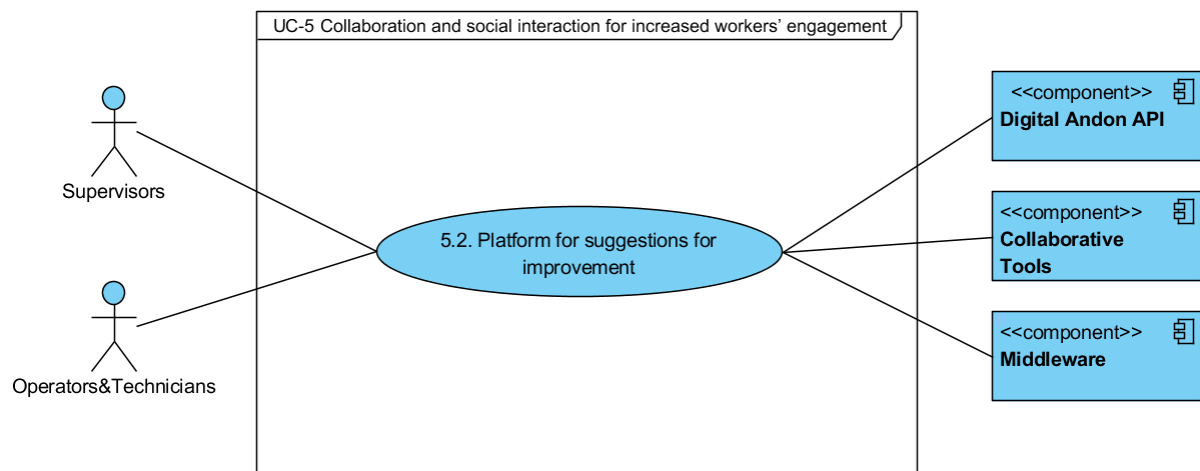


Figure 97 Analysis of UC-5.2

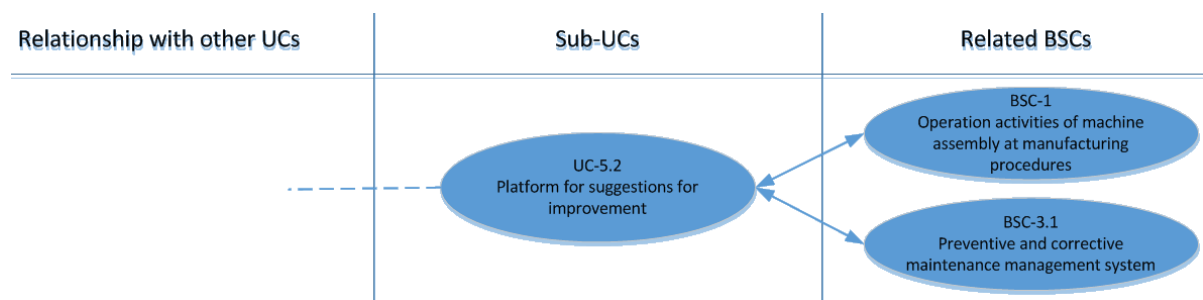


Figure 98 Relationship of UC-5.2 with other UCs and BSCs

At the following table there is an analysis of the Use Case 5.3 according to the template that has been used.

Table 61 UC-5.3 Gamified Platform for suggestions for improvement

Use Case #	UC-5.3
Use Case Name	Gamified Platform for suggestions for improvement
Version/Author	v2 / FIT
Brief Description	<p>This UC extend UC-5.2 by introducing gamification for motivating users.</p> <p>In the suggestions for improvement platform, workers submit suggestions for process or other improvements over an electronic system to decision makers. All submitted suggestions can be watched and voted anonymously from the workers.</p> <p>The workers can collect points for the same gamification framework instance using</p>

	the suggestions for improvement platform. That means they get a certain amount of points for each task they perform using this platform.
Pre-conditions	Not Applicable
Post-conditions	Minimal Guarantees: Logging of suggestions for improvement Success Guarantees: A suggestion for improvement reaches the person who can decide on it. The worker gets feedback whether his suggestion was applied and, in case of rejection, the reason for the rejection.
Goal (Successful End Condition)	Improve the process of workers make suggestions for process improvements
Use Case Initiation	Worker identifies potential for improvement and decides to make a suggestion
Involved Actors	Supervisors, Operators & Technicians
Architecture Components Involved	Digital Andon API, Collaborative Tools, Gamification Framework, Middleware
Related Business Scenario	BSC-1, BSC-3.1
Relationship with other Use Cases	UC-5.1, UC-5.3
Addressed requirements of the system	SAFA IDs: 143, 41
Restrictions	-

The next two figures present the connection of the Use case with the SatisFactory components and with the Business Scenarios and the other Use Cases.

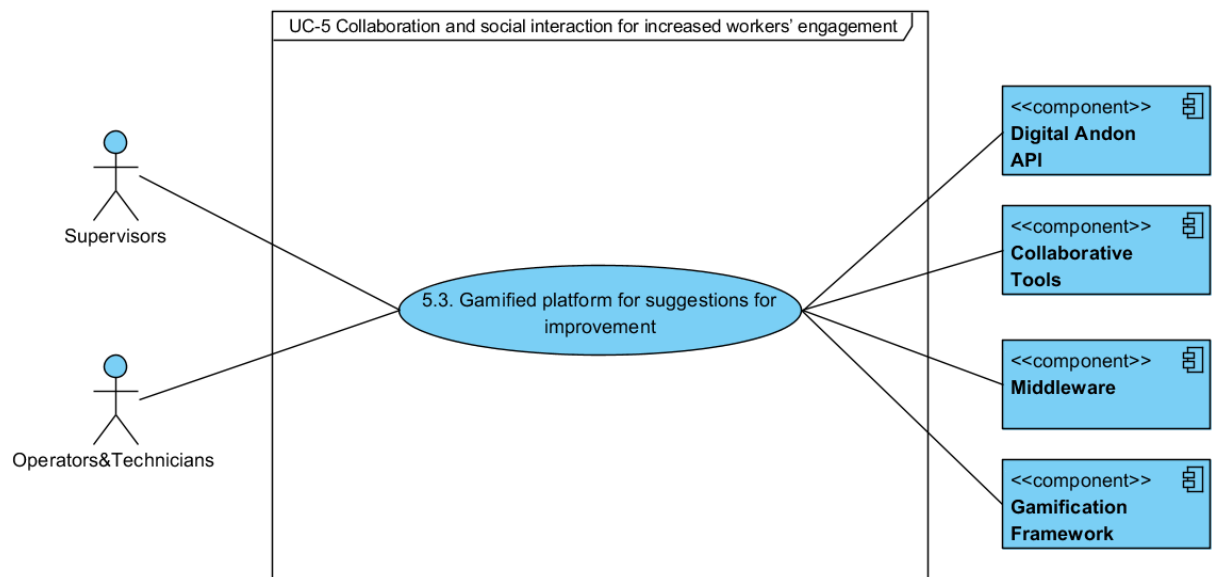


Figure 99 Analysis of UC-5.3

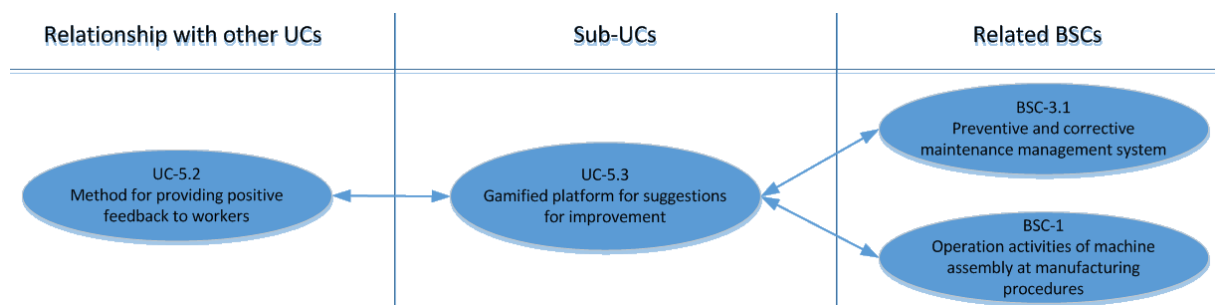


Figure 100 Relationship of UC-5.3 with other UCs and BSCs

At the following table there is an analysis of the Use Case 5.4 according to the template that has been used.

Use Case #	UC-5.4
Use Case Name	Instantiation of Gamification Framework
Version/Author	v1 / FIT
Brief Description	<p>This UC is related to formulating a system that motivates the workers to engage at the instantiation of the Gamification Framework regularly. The system does this through gamification which increases the motivation of the workers to keep up their engagement with the Gamified Framework.</p> <p>Upon detection of actor's engagement, the system records the respective actions / feedback and the actor earns points. These points are added to the aggregated score of her global team that always compete against their own best day score.</p>

Pre-conditions	Worker identification at the system where the instantiation of Gamification Framework is deployed
Post-conditions	The worker has earned points according to the Gamification process he followed
Goal (Successful End Condition)	Motivate worker to engage at the instantiated game in order to improve work satisfaction
Use Case Initiation	Worker uses the instantiation of the Gamification Framework
Involved Actors	Supervisors, Operators & Technicians
Architecture Components Involved	Collaborative Tools, Gamification Framework, Digital Andon API
Related Business Scenario	BSC-4.3, BSC-5.3
Relationship with other Use Cases	UC-5.2
Addressed requirements of the system	SAFA IDs: 220, 215, 205, 146, 136, 105, 41, 17, 4
Restrictions	-

The next two figures present the connection of the Use case with the SatisFactory components and with the Business Scenarios and the other Use Cases.

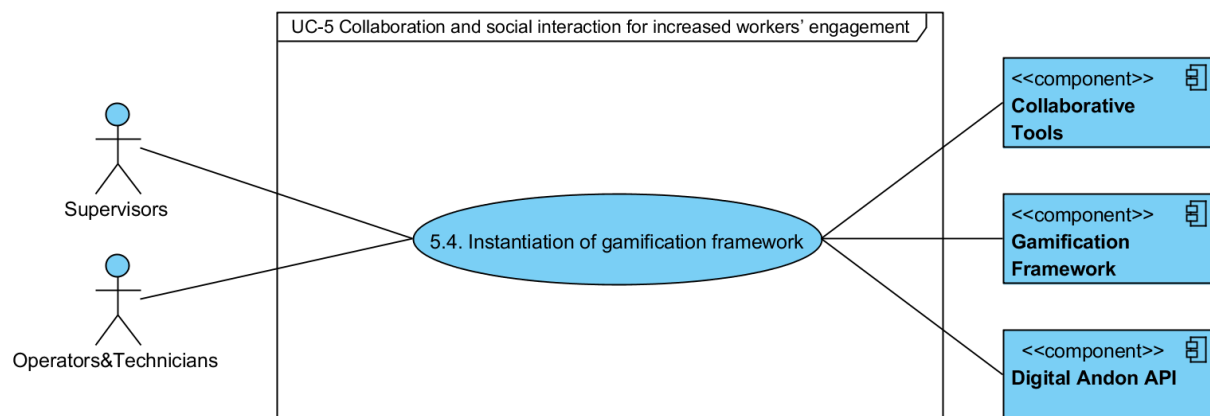


Figure 101 Analysis of UC-5.4

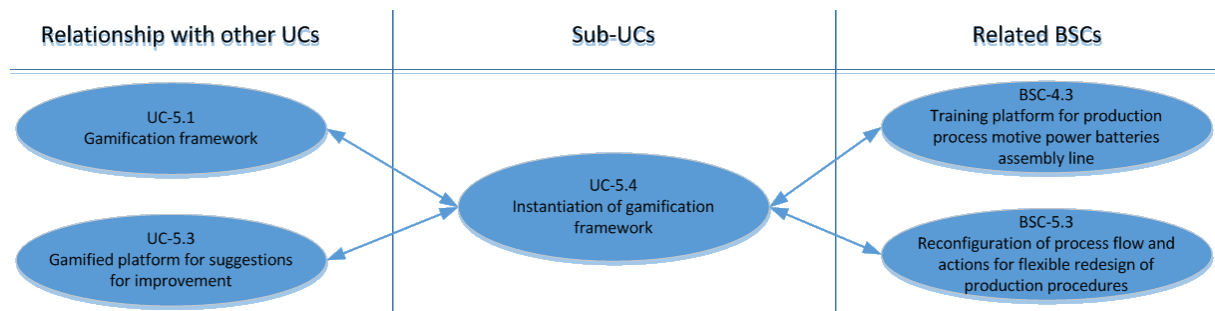


Figure 102 Relationship of UC-5.3 with other UCs and BSCs

6.5.6 UC-6 Presentation of activities and bidirectional communication for enhanced shop floor feedback

The last set of Use Cases is about presenting several activities and actions of the shop floor using advanced visual representation. Using the AR platform and the Multi-Modal Augmented HMIs the system helps workers to have a better view of the shop floor and of the actions they have to perform. Another function which is implemented on these Use Cases is the knowledge sharing among workers. This will be useful mostly for the new employees who will be able to use the knowledge of the experienced workers to some demanding and difficult operations. The following figure shows the relationship between the workers, the Use Cases and the components that will be used. Finally the UCs that belong to this category describe the use of the AR Glasses for the presentation of information to the actors.

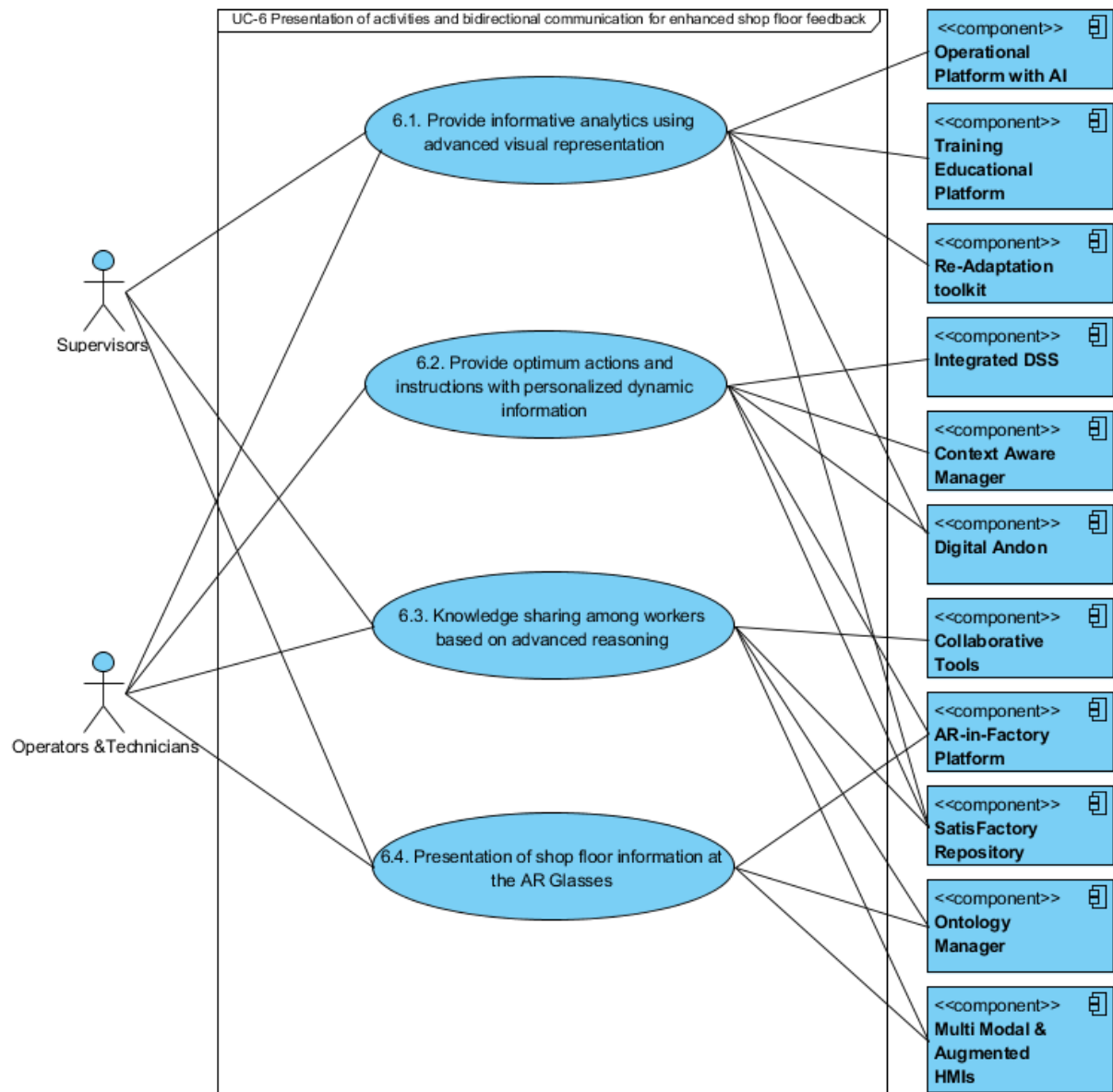


Figure 103 Analysis of UC-6

At the following table there is an analysis of the Use Case 6.1 according to the template that has been used.

Table 62 UC-6.1 Provide informative analytics using advanced visual representation

Use Case #	UC-6.1
Use Case Name	Provide informative analytics using advanced visual representation
Version/Author	v1 / CERTH/CPERI (CZ)

Brief Description	This UC is responsible for the presentation of information requested by the actors using the Multi Modal HMIs. The components that belong to the Services Layer of the SatisFactory platform communicate with the actors through the HMIs where the results from the execution of the necessary operation by the component are available to the end users. Besides these results, the Visual Analytics module is available to elevate the distributed information from the various sources such as the SatisFactory Repository and the iDSS to actionable knowledge to the actors of the platform.
Pre-conditions	The components of the visualization Toolkit receive the appropriate information from the components that are responsible for the data and information processing. The data formats and their visualization could change according to the platforms using the Training Educational Platform and Operational Platform with Augmented Intelligence. The physical equipment allowing the data analytics querying and visualization could be different from those used by the shop floor operator or, even, could be not accessible.
Post-conditions	Requested Information and derived analytics are available through the UIs of the SatisFactory platform.
Goal (Successful End Condition)	The information is delivered to the actors that initiate the request.
Use Case Initiation	The UC is automatically initiated in order to provide the SatisFactory information to the Visualization Toolkit requested by the involved actors.
Involved Actors	Supervisors, Operators & Technicians
Architecture Components Involved	Digital Andon, SatisFactory Repository, Multi Modal & Augmented HMIs, Re-Adaptation toolkit, Multi Modal & Augmented HMIs
Related Business Scenario	BSC-1, BSC-2, BSC-3, BSC-4, BSC-5
Relationship with other Use Cases	UC-5.1, UC-5.2
Addressed requirements of the system	SAFA IDs: 229, 189, 155, 136 , 69, 65, 41, 40, 37
Restrictions	-

The next two figures present the connection of the Use case with the SatisFactory components and with the Business Scenarios and the other Use Cases.

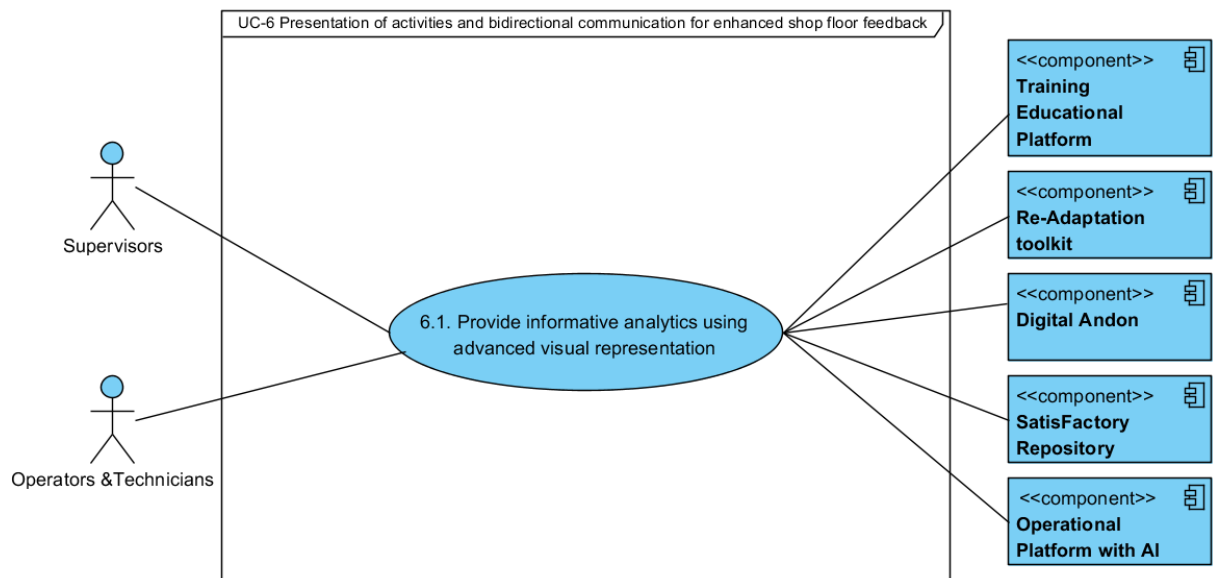


Figure 104 Analysis of UC-6.1

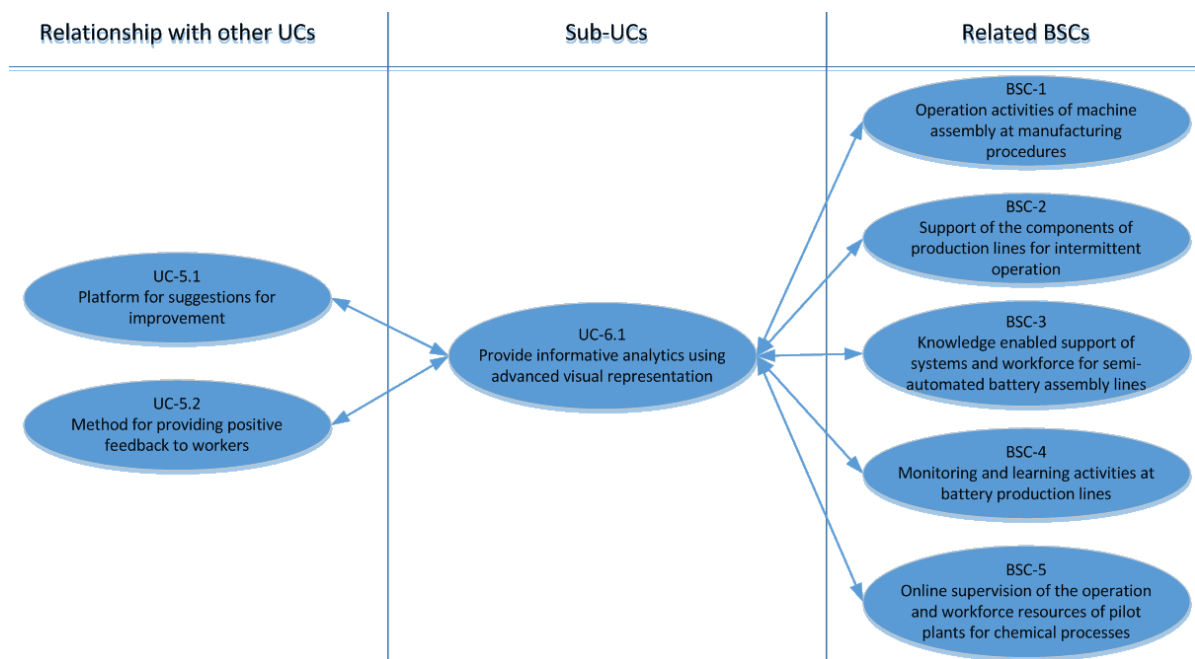


Figure 105 Relationship of UC-6.1 with other UCs and BSCs

At the following table there is an analysis of the Use Case 6.2 according to the template that has been used.

Table 63 UC-6.2 Provide optimum actions and instructions with personalized dynamic information

Use Case #	UC-6.2
Use Case Name	Provide optimum actions and instructions with personalized dynamic information
Version/Author	v1 / CERTH/CPERI (CZ)
Brief Description	<p>This UC deals with the presentation of the actions and instruction to the involved actors as a result from the execution of the respective components. The components that belong to the Services Layer of the SatisFactory platform communicate with the actors through the HMIs where the results from the execution of the necessary operation by the component are available to the end users.</p> <p>The provided information is personalized depending on the actor and the activity that needs to be performed and consider workers existing workload in order to balance the distribution of actions in an optimum manner. When available, by the nature of the procedure, the respective actions are presented using the Digital andon while the integrated DSS is responsible for suggesting the optimum course of events that will make the implementation of the actions taking into consideration the wellbeing and comfort of the worker.</p>
Pre-conditions	The components of the Multi Modal and Augmented HMIs receive the information to be presented from the components that are responsible for the data and information processing.
Post-conditions	Requested Information and derived instructions are available through the UIs of the SatisFactory platform.
Goal (Successful End Condition)	The information is delivered to the actors that initiate the request.
Use Case Initiation	The UC is initiated when an actor request for instruction or action for the implementation of a procedure at the shop floor.
Involved Actors	Operators & Technicians
Architecture Components Involved	Integrated DSS, AR-in-Factory Platform, SatisFactory Repository, Digital Andon, Context Aware Manager
Related Business Scenario	BSC-1, BSC-2, BSC-3, BSC-4, BSC-5
Relationship with other Use Cases	UC-2, UC-3, UC-4, UC-5
Addressed requirements of the system	SAFA IDs: 229, 189, 155, 136, 79, 41, 40
Restrictions	-

The next two figures present the connection of the Use case with the SatisFactory components and with the Business Scenarios and the other Use Cases.

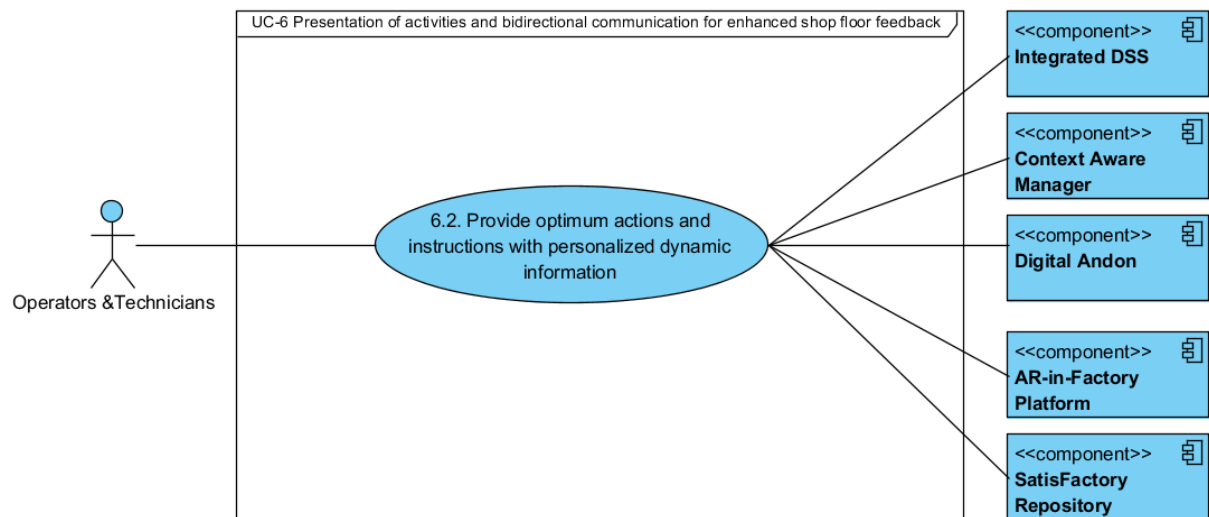


Figure 106 Analysis of UC-6.2

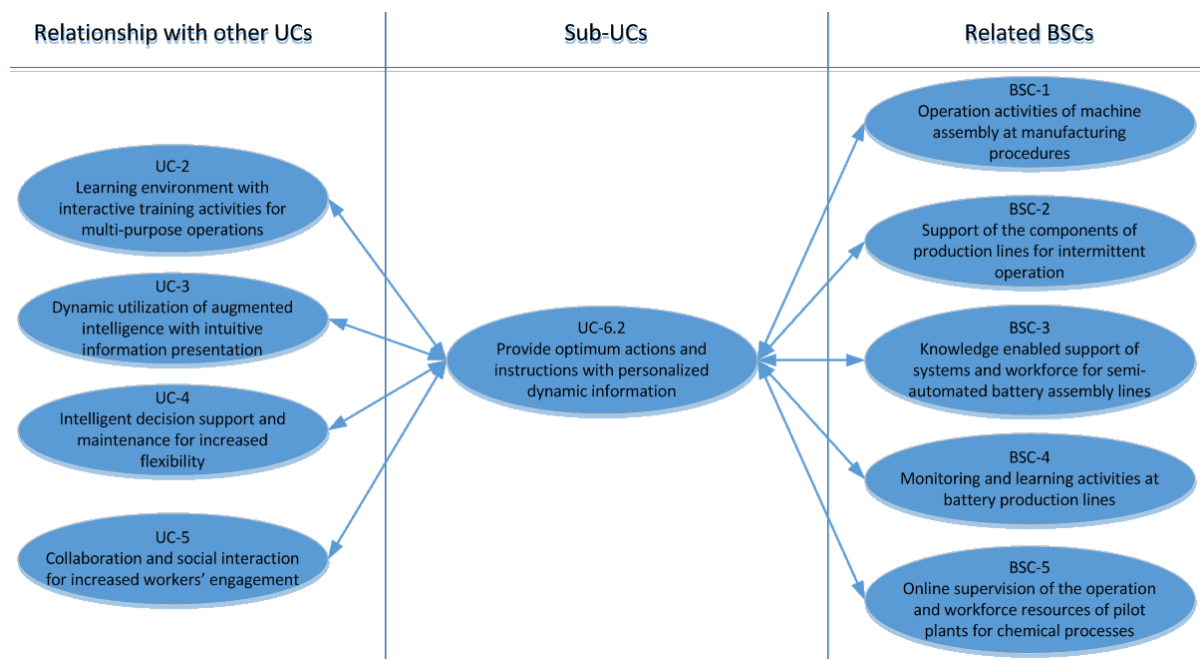


Figure 107 Relationship of UC-6.2 with other UCs and BSCs

At the following table there is an analysis of the Use Case 6.3 according to the template that has been used.

Table 64 UC-6.3 Knowledge sharing among workers based on advanced reasoning

Use Case #	UC-6.3
Use Case Name	Knowledge sharing among workers based on advanced reasoning
Version/Author	v1 / CERTH/CPERI (CZ)
Brief Description	This UC involves the use of the adaptive and augmented interfaces to present the necessary information upon request by the involved actors. The sharing of knowledge is achieved by the engagement of the workers through the Collaboration tools. The knowledge sharing is achieved by using the presentation of the context aware information, which is translated into actionable knowledge and recommendations. In this UC the procedures that involve the visualization of data using advanced reasoning methods for enhanced shop floor feedback are demonstrate at indicative nominal and not nominal situations.
Pre-conditions	The components of the Multi Modal and Augmented HMIs receive the information to be presented from the components that are responsible for the data and information processing.
Post-conditions	Knowledge creation through the aggregation of information data coming from the shop floor. Requested Information and material for shop floor operations are available through the UIs of the Satisfactory platform.
Goal (Successful End Condition)	The information is delivered to the actors that initiate the request.
Use Case Initiation	The UC is initiated when an actor requests or searches for information about a procedure, an action or material about the shop floor operations.
Involved Actors	Supervisors, Operators & Technicians
Architecture Components Involved	Collaborative Tools, Multi Modal & Augmented HMIs, Satisfactory Repository, Ontology Manager
Related Business Scenario	BSC-1, BSC-2, BSC-3, BSC-4, BSC-5
Relationship with other Use Cases	UC-3, UC-4, UC-5
Addressed requirements of the system	SAFA IDs: 118, 117, 101, 59, 58, 41, 4
Restrictions	-

The next two figures present the connection of the Use case with the Satisfactory components and with the Business Scenarios and the other Use Cases.

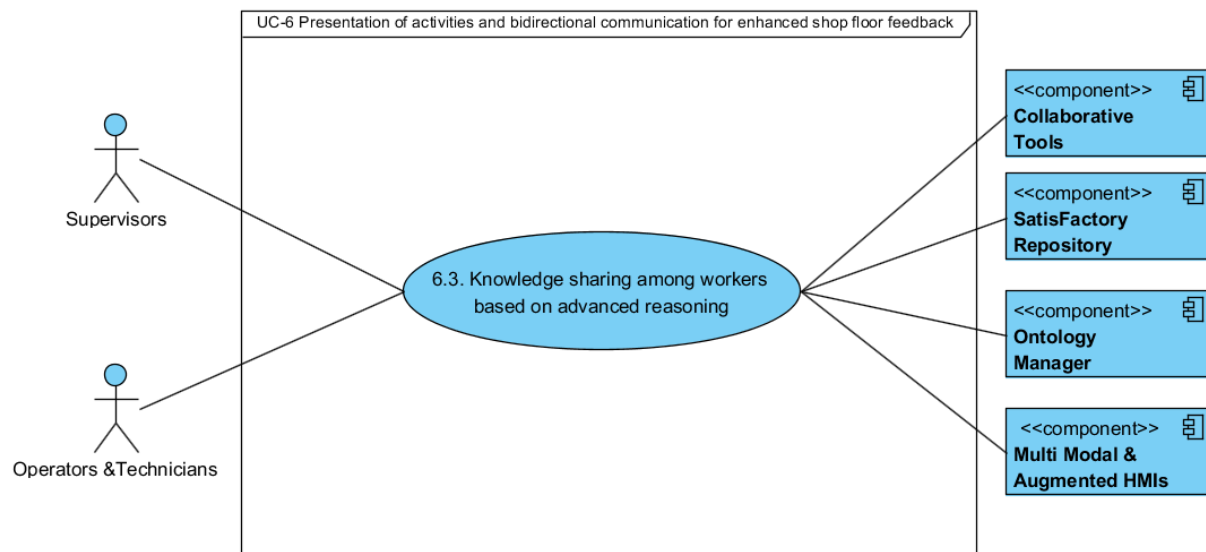


Figure 108 Analysis of UC-6.3

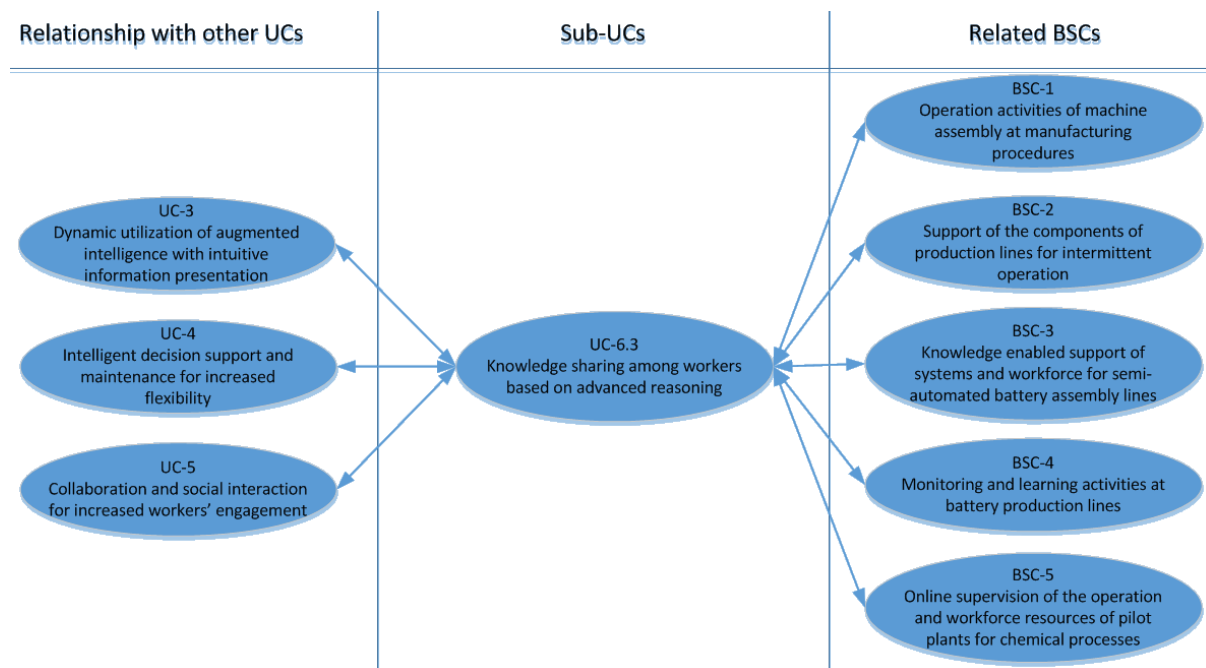


Figure 109 Relationship of UC-6.3 with other UCs and BSCs

At the following table there is an analysis of the Use Case 6.4 according to the template that has been used.

Table 65 UC-6.4 Presentation of shop floor information at the AR Glasses

Use Case #	UC-6.4
Use Case Name	Presentation of shop floor information at the AR Glasses
Version/Author	v1 / CERTH/CPERI (CZ)
Brief Description	<p>This UC is responsible for providing information to the involved actors through the AR Glasses utilizing the online information and signal from the SSN in combination with the static information as stored at the Repository.</p> <p>The actors will be able to view the notification and the real-time data from the shop floor as the various procedures dynamically evolve. The Glasses UI will be adjusted depending on the context of use and the end user will monitor the respective predefined information in an intuitive manner without disrupting the operations.</p> <p>The AR Glasses show repair instructions to the user and send images related to the status of the procedures or the real-time values acquired by the SSN of the shop floor.</p>
Pre-conditions	Not Applicable
Post-conditions	The requested information is shown at the AR Glasses UI.
Goal (Successful End Condition)	The main goal of this UC is the presentation of requested information to the Glasses UI as the various operations are evolving by combining both static and dynamic data from the shop floor.
Use Case Initiation	The UC is initiated when an actor performs specific actions where the AR Glasses deliver important and online information about the real-time status of the system at the shop floor or information about the steps to be implemented by the actor.
Involved Actors	Operators & Technicians, Supervisors
Architecture Components Involved	AR in-Factory Platform, Multi Modal & Augmented HMIs, Ontology Manager
Related Business Scenario	BSC-2, BSC-3, BSC-5.1, BSC-5.2
Relationship with other Use Cases	UC-2, UC-3, UC-4
Addressed requirements of the system	SAFA IDs: 229, 140, 132, 115, 75, 73, 69, 13
Restrictions	The presentation tools, thanks to their capability to act as "View Channel" can be used to visualize alarm and any information messages only. In order to

	accomplish the UC requirements, a higher level system should use the AR tools to support workers to solve a complex problem.
--	--

The next two figures present the connection of the Use case with the SatisFactory components and with the Business Scenarios and the other Use Cases.

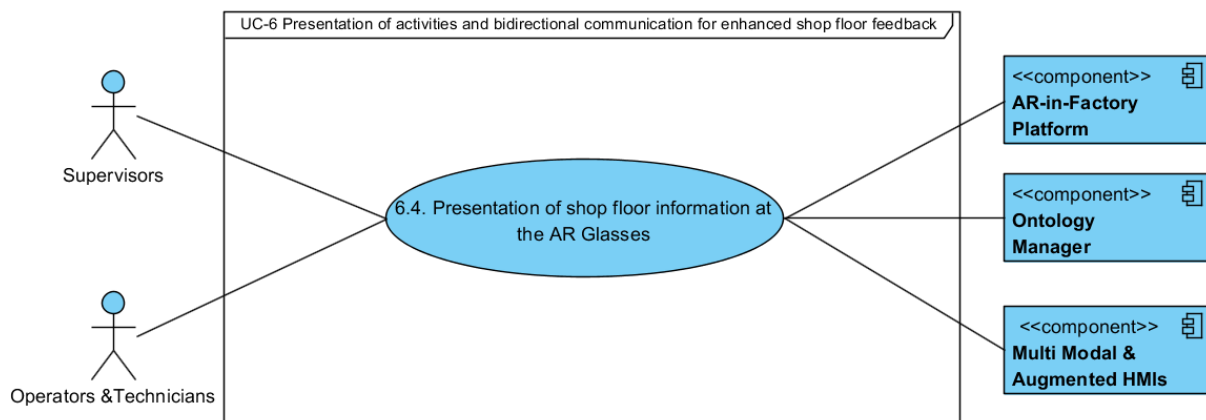


Figure 110 Analysis of UC-6.4

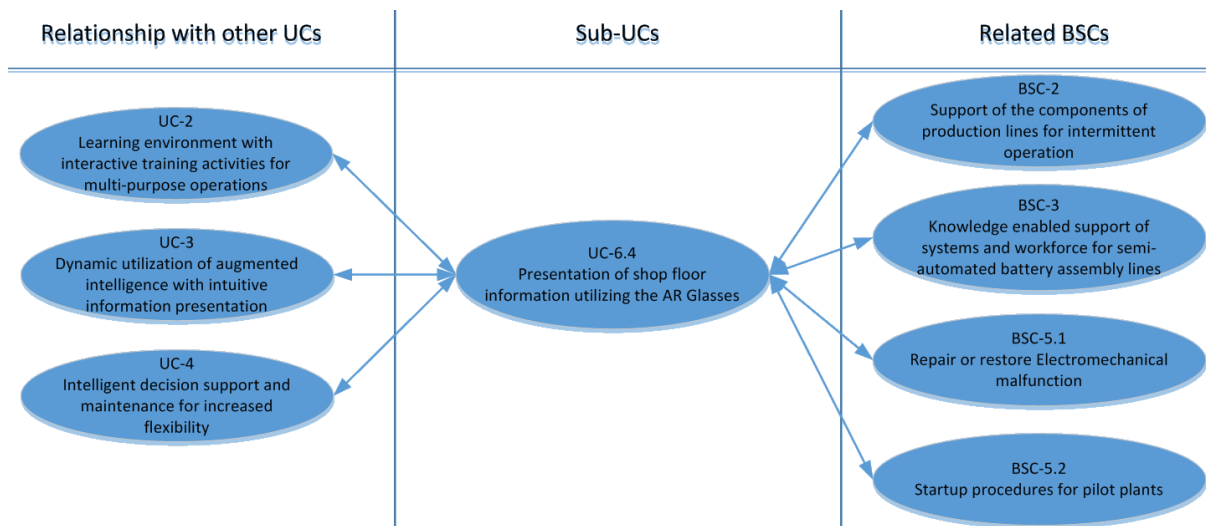


Figure 111 Relationship of UC-6.4 with other UCs and BSCs

7 ASSESSMENT OF APPLICATION SCENARIOS, USE CASES AND REQUIREMENTS

This Chapter provides a comprehensive assessment of the Application Scenarios, the UCs, the involved actors and the procedures that are performed at the three shop floors of SatisFactory project. The scope of Chapter 7 is to present the relationship of the Application Scenarios with the Use Cases and with the SatisFactory objectives. A brief description of each component can be found at “Annex 3 – Description of the Architecture Components”. All the tables and the diagrams of this chapter have been revised for the final version of the Deliverable D1.2 since the data that are analysed have also been revised. Moreover, this Section is the first step towards the creation of the vocabulary, which constitutes the hyper ontology of the envisioned CIDEM described in details at task T1.4 of the project. The last paragraph of this chapter refers to the response strategies of the project. These strategies are the actions which are triggered from all the rules and signals on each BSC. They are separated into categories based on the type of the event that triggers the strategy.

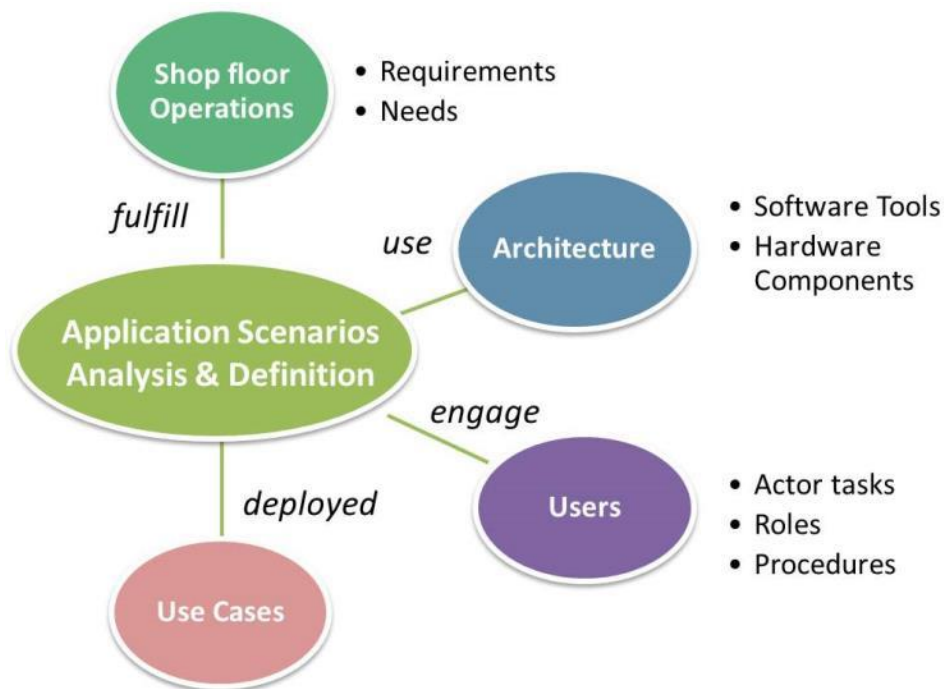


Figure 112 Connection of Application Scenarios with Operations, Architecture, Use Cases and Actors

7.1 APPLICATION SCENARIOS CONNECTION TO THE USER NEEDS AND REQUIREMENTS

Each Application Scenario is developed according to the user needs and requirements that were identified by the interviews and the system functionalities as documented at deliverable D1.1. This Section summarizes the connection of the Application Scenarios and the project identified needs and requirements. A detailed description of the identified needs and requirements can be found at

“Annex 2 – Requirements Description”, where the SAFA (SatisFactory) requirement ID (SAFA-ID) and the respective description are documented. Furthermore the analysis moved one step ahead to the supervisory understanding of the Application Scenarios and what they will fulfil. Based on the analysis of the interviews a set of categories are defined in order to group the user needs and requirements and to subsequently correlate them with the candidate Application Scenarios. SatisFactory requirements are grouped into 11 categories that are described at Table 66.

Table 66 Categories of Requirements

Communication
Requirements which are related to two or more people communication with each other. It can involve platforms for organizing and sharing information or requirements for direct communication. Generally, the requirements aim at better transmitting information from one person to the other.
Further Education
While “Training” addresses the learning of every-day tasks at work, “Further Education” addresses to learn something beyond this. This can be knowledge which is useful for a work task in the future at the same factory or even knowledge which is useful for another job in a different company in the future.
Motivation
Requirements which aim at improving the motivation of workers to work. This can involve motivators to start working or, for example, positive feedback for work done.
Organization
Requirements which deal with managing and organizing work tasks. Secondly, it addresses requirements which analyze the way of work in the pilots. For example, time schedules, work conditions, environment.
Productivity
Requirements which are related to improving the productivity of work, i.e. to make particular work tasks easier, faster, and cheaper or increase the quality of the outcome.
Problem to Solve
Requirements which deal with the identification of a specific problem and this can be overcome.
Safety
Requirements that aim improving the safety of the workplace. For example, the detection of potential dangers, support and pro-active prevention, improvement of health conditions.
Satisfaction
Generic category for everything which is related to the satisfaction of the workers at the workplace and that does not fit to one of the other categories.
Teamwork
Requirements which are related to two or more people achieve a goal together. Second aspect is team building.
Training
Requirements which aim at facilitating to learn work-related tasks or behavior. This includes teaching others and self-learning possibilities.
Usability
Requirement which define how the product shall be used, i.e. describing properties of users and use contexts.

Initially a connection with the group of requirements is performed in order to identify which categories of requirements are covered by each Application Scenario.

Table 67 Connection of Application Scenarios with the group of requirements

Application Scenarios ID	Categories										
	Communication	Further Education	Motivation	Organization	Productivity	Problem to Solve	Safety	Satisfaction	Teamwork	Training	Usability
BSC-1.1											
BSC-1.2											
BSC-2.1											
BSC-3.1											
BSC-4.1											
BSC-4.2											
BSC-4.3											
BSC-5.1											
BSC-5.2											
BSC-5.3											
BSC-6.1											

It is obvious that most of the categories are met at the majority of the Application Scenarios. This means that the Application Scenarios are multi-purpose and cover different aspects of the project. The second part of the Application Scenario analysis with respect to the requirements shows the number of requirements that are fulfilled.

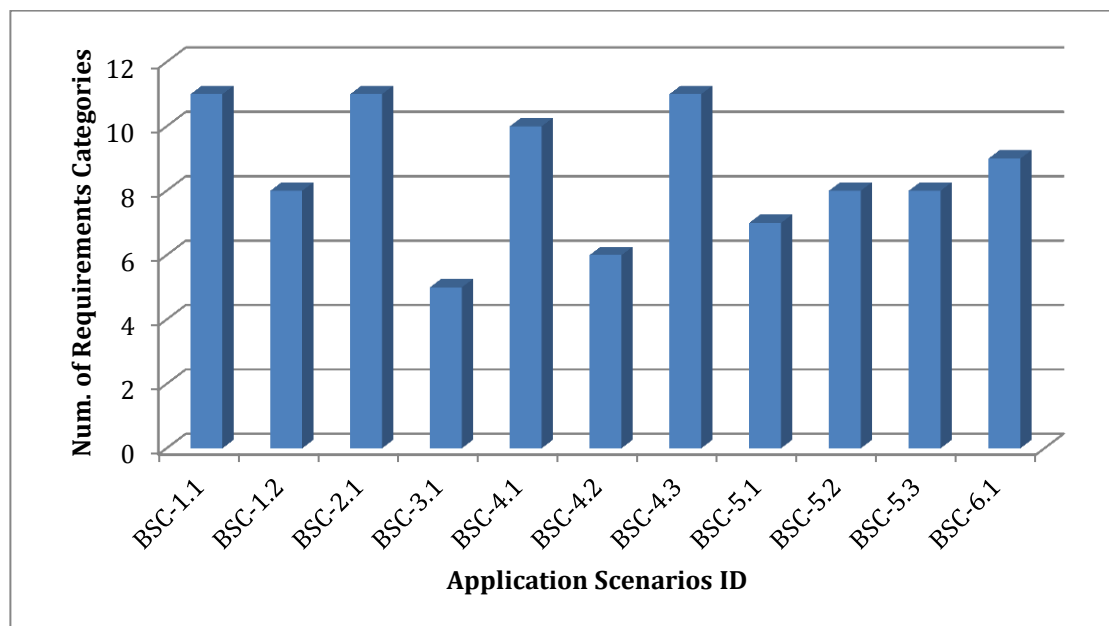


Figure 113 Application Scenarios and Number of requirements

The above figure is derived from the previous table and summarizes the number of the categories of the requirements that are used at each of the Application Scenarios. As it can be seen, each Application Scenario fulfills requirements of many categories which mean that the result of SatisFactory has the potential to significantly affect the operations and daily behavior at the shop floors.



7.1.1 Application Scenarios and Use Cases

A very import parameter of the implementation of the SatisFactory project is the relationship between the Application Scenarios and the Use Cases. In order for the Application Scenarios to be implemented and satisfy the requirements they must include some functions. These functions are met at the Use Cases that have been created and will be analyzed further in the document. The following table shows which Use Cases are used at each of the Application Scenarios.

Table 68 Relationship between Application Scenarios and Use Cases

Application Scenarios	COMAU			SUNLIGHT				CERTH			
Use Cases	BSC-1.1	BSC-1.2	BSC-2.1	BSC-3.1	BSC-4.1	BSC-4.2	BSC-4.3	BSC-5.1	BSC-5.2	BSC-5.3	BSC-6.1
1.1 Process for handling shop floor related information (data acquisition)	√	√	√	√	√	√		√	√	√	
1.2. Storage of the shop floor information and data from the multi-sensorial networks (storage of data to repository)	√	√	√	√	√	√		√	√	√	√
1.3. Analysis of real-time and historical info from the shop floor			√	√	√	√		√			√
2.1 In-factory training and support of workers using a flexible learning platform	√	√	√		√		√				
2.2 Validation of training actions performed at the shop floor	√	√	√		√		√	√	√		√
2.3 Presentation of the shop floor procedures utilizing heterogeneous material (work orders, manuals, schematics)	√	√	√		√		√	√		√	
3.1 Online recognition of workers activities	√	√	√	√	√	√	√	√	√	√	√
3.2 Incident identification based on dynamically evolving operations											√
3.3. Monitoring and online notification of abnormal events or alarms			√			√		√			√
3.4. Identification of worker's and equipment's location								√	√		√
4.1. Provide maintenance work plans and actions related to human-centric activities			√	√				√	√	√	
4.2. Acquire work schedules and sequence of actions	√	√	√	√	√	√	√	√	√	√	
4.3. Monitoring and decision support of operations and maintenance procedures	√	√	√	√	√	√	√	√	√	√	
4.4. Provide workers availability and allocation of resources			√	√				√		√	
4.5 Worker comfort level notifications under varying environmental conditions								√	√	√	
5.1 Gamification framework	√	√	√	√	√	√	√	√	√	√	
5.2. Platform for suggestions for improvement	√	√		√							
5.3. Gamified Platform for suggestions for improvement	√	√		√							
5.4 Instantiation of Gamification Framework							√			√	
6.1. Provide informative analytics using advanced visual representation	√	√	√	√	√	√	√	√	√	√	
6.2. Provide optimum actions and instructions with personalized dynamic information	√	√	√	√	√	√	√	√	√	√	
6.3. Knowledge sharing among workers based on advanced reasoning	√	√	√	√	√	√	√	√	√	√	
6.4. Presentation of shop floor information at the AR Glasses			√	√				√	√		

7.1.2 Application Scenarios and involved Actors

Another important aspect of SatisFactory project is the collaboration of the actors which was taken into account during the process of developing the candidate Application Scenarios. The objective was to involve actors from more than one group in order to show the potential for collaboration between them and the utilization of the SatisFactory tools to a wide scope of workers.

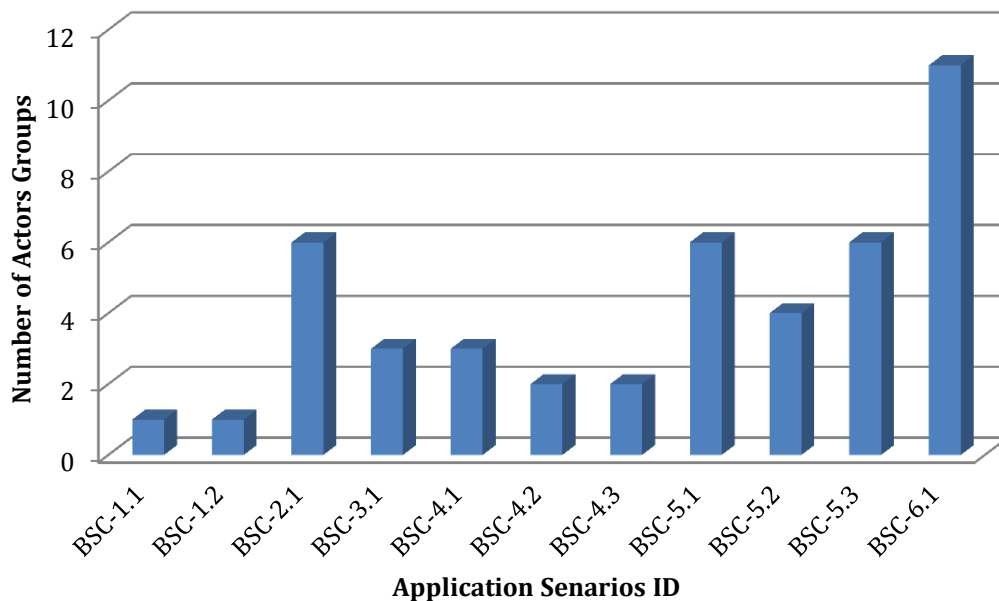


Figure 114 Application Scenarios and involved Actor Groups

The above figure describes how many of the Actors' groups per each shop floor are involved in every Use Case. Useful information that can be extracted from the diagram is that in all three shop floors most of the Actors' groups are involved in all Use Cases, which mean that the SatisFactory project will affect many of the employees of the End-User partners.

7.2 CONNECTION OF APPLICATION SCENARIOS WITH THE PROJECT OBJECTIVES

The candidate Application Scenarios were formulated with the consideration of project objectives as this is the main driver for the demonstration of the technological developments of SatisFactory platform. The main objectives of the SatisFactory project are:

- **Objective 1:** Context aware control and re-adaptation of shop floor production facilities for increased productivity and flexibility in use of shop floor resources
- **Objective 2:** Improvement of attractiveness and productivity through collaboration, social interaction and gamification approaches
- **Objective 3:** Real-time knowledge-sharing and AR-based collaboration and training services
- **Objective 4:** Improved shop floor feedback and decision making for gains in productivity, workers wellbeing and comfort

- **Objective 5:** Adaptive and augmented interfaces for collaboration, knowledge sharing and real time support

Table 69 presents the connections between the Application Scenarios and the project objectives.

Table 69 Use Case and SatisFactory Objectives

Appl. Scenarios	Objective 1	Objective 2	Objective 3	Objective 4	Objective 5
BSC-1.1	✓			✓	✓
BSC-1.2	✓			✓	✓
BSC-2.1		✓	✓		✓
BSC-3.1	✓			✓	
BSC-4.1	✓			✓	✓
BSC-4.2			✓		
BSC-4.3		✓	✓		
BSC-5.1	✓		✓	✓	✓
BSC-5.2	✓		✓		✓
BSC-5.3	✓		✓	✓	✓
BSC-6.1				✓	

It is observed from the aforementioned analysis that every aspect of the project objectives is covered and not by just one Application Scenario, which means that a multitude of options are available to demonstrate the potential and validate the effect of SatisFactory platform to the involved shop floors.

7.2.1 Priorities of Application Scenarios for deployment

The aforementioned Application Scenarios have been thoroughly examined by all partners of the consortium in order to select for implementation the functions that are more important to demonstrate the objectives of the SatisFactory project. An analysis by the end users is performed that prioritize the Application Scenarios that can be seen at Table 70.

Table 70 End-Users Application Scenarios desired priority

Priority	End Users		
	COMAU	SUNLIGHT	CERTH
1	BSC-1.1 - Robot Wrist Assembly	BSC-4.2 - Monitoring of the Cell Temperature during Jar formation and data collection	BSC-5.1 – Repair or restore an electromechanical malfunction
2	BSC-1.2 - Welding Gun Body Assembly	BSC-3.1 - Preventive maintenance management system	BSC-6.1 - Recognition of incidents and path optimization for workers movement on the shop floor
3	BSC-2.1 - Remote Assistance	BSC-4.3 - Training platform for motive power batteries assembly line	BSC-5.2 - Start-up procedures of VB01 Hydrocracking pilot plant
4		BSC-4.1 - Motive power battery assembly line	BSC-5.3 - Reconfiguration of process flow and actions for flexible redesign of production procedures

The priorities are set by the importance of the activities foreseen at each Application Scenario and in conjunction with the current status of the shop floor. The selection of the Application Scenarios, as a whole or in parts for selected actions, will be clearly demonstrated at the respective deliverables D5.3 and D5.4 (related to the deployment at the shop-floors).

7.3 RESPONSE STRATEGIES AT SATISFACTORY

There are several actions that are triggered automatically during the BSCs at all three shop floors. These actions have been grouped into categories depending on the kind of the event that triggers them. These categories are:

- Geo-fencing Events:
These events are generated by the Localization Manager when a worker is inside a forbidden area. The workers are equipped with the UWB wearable device.
- Presence Detection Events:

These events are generated by the GCRM when a worker is inside a forbidden area monitored by the camera.

- Gear Detection Events:

These events are generated by the GCRM when a worker does not wear the safety equipment such as helmet, gloves and jacket.

- Fall Detection Events:

These events are generated by the GCRM when a worker falls in the area monitored by the camera and by the thermal camera depending on the movements at the shop floor.

The response strategies vary depending on the shop floor due to the different kind of tasks that are taking place at each of them. The following paragraphs describe these strategies per shop floor.

7.3.1 Response Strategies to Shop floor Incidents/Events at COMAU shop floor

The response strategies that are triggered at the shop floor of COMAU are:

- When a Geo-fencing or a Presence Detection Event happens then
 - ✓ The production line is working in “safe condition” if possible, or it is stopped immediately
 - ✓ According to the specific risk analysis a display in the shop floor visualizes an alert message
 - ✓ The supervisor receives an alarm on his mobile device
 - ✓ The worker whose actions triggered the event visualizes a message on his glasses or on his mobile device
- When a Gear Detection Event happens then
 - ✓ A display in the shop floor visualizes an alert message
 - ✓ The safety supervisor receives an alarm on his mobile device
 - ✓ The worker who does not wear the correct safety equipment is alerted by the system

7.3.2 Response Strategies to Shop floor Incidents/Events at Sunlight shop floor

The response strategies that are triggered at the shop floor of Sunlight are:

- When a Geo-fencing or a Presence Detection Event happens then
 - ✓ An audible alarm will sound within the forbidden area
 - ✓ An optical alarm (flashing beacon) will initiated (red colour)
 - ✓ The worker that has entered in the forbidden area will feel a vibration on his wearable
 - ✓ The workers that are closer to the worker that has entered in the forbidden area will feel also the vibration on the wearable device
 - ✓ The foreman will receive in his smart phone/tablet or glasses the id of the worker and his position
 - ✓ The incident will be logged and sent to the health and safety manager
- When a Gear Detection Event happens then

- ✓ The foreman will receive a notification in his smart phone/tablet or glasses
- ✓ The notification will include the ID of the worker, his accurate position at the shop floor and his contact details (phone number or email)
- ✓ The worker will hear a warning message from his wearable which will be repeated until he wears his protection equipment
- When a Fall Detection Event happens then
 - ✓ An audible alarm will sound close to this particular point in order to warn the vehicles and the rest of the workers that somebody or something is on the floor
 - ✓ An optical alarm (flashing beacon) will initiated in the closest point (orange colour)
 - ✓ The responsible foreman will receive a notification in his smart phone/tablet or glasses
 - ✓ The incident will be logged and sent to the health and safety manager and to the doctor of the factory (if the incident is related with a health issue).

7.3.3 Response Strategies to Shop floor Incidents/Events at CERTH/CPERI shop floor

The response strategies that are triggered at the shop floor of CERTH/CPERI are:

- When a Geo-fencing or a Presence Detection Event happens then
 - ✓ An acoustic alarm in the shop floor is activated
 - ✓ A display in the shop floor visualizes an alert message
 - ✓ The supervisor receives an alarm on his mobile device
 - ✓ The worker who approaches the forbidden visualizes a message on his glasses
 - ✓ The worker who approaches the forbidden area receives an acoustic alert and a message on his mobile device
- When a Gear Detection Event happens then
 - ✓ A display in the shop floor visualizes an alert message at the screen near the worker
 - ✓ The worker who doesn't use one or more of his safety equipment visualizes a message on his glasses
 - ✓ The worker who doesn't use one or more of his safety equipment receives an acoustic alert
- When a Fall Detection Event happens then
 - ✓ An acoustic alarm in the shop floor is activated
 - ✓ The supervisor or the responsible personnel and the floor manager receive an alarm on their mobile devices and/or on their glasses
 - ✓ A display in the shop floor visualizes an alert message

7.3.4 Summary of the Response Strategies at SatisFactory

There has been an effort to include response strategies for all incidents of the BSCs at the three shop floors. One of the main goals was to take advance of the utilities and the capabilities of all the

involved components of the SatisFactory platform, in order to have the optimal result. We have separated the response strategies into the following categories:

1. Visualization at the AR glasses of the abnormal event (worker or supervisor)
2. Local display at the shop floor
3. Signal to the production line/ process HMI
4. Notification of the supervisor/foreman at the mobile device
5. Personalized notification to the worker/appropriate
6. Shop floor level notification - dedicated alarm system (horn or light beacon)
7. Notification through vibration of the wearable device (personalized and/or targeted actors)

The following table shows at which of the three shop floors every category is applicable:

Table 71: Response strategy categories at the SatisFactory shop floors

	COMAU	SUNLIGHT	CERTH
1. Visualization – AR Glasses	X	X	X
2. Local display @shop floor	X		X
3. Interaction with prod. Line/process	X		X
4/5. Notification @mobile	X	X	X
6. Shop floor alarm		X	X
7. Wearable vibration/sound		X	X

8 CONCLUSIONS

The initial phase of SatisFactory has focused on the specification of use cases, the definition of basic SatisFactory actors, as well as the description of a number of user-centred operating procedures and associated classification of operations, to illustrate how the deployment of SatisFactory platform is envisioned in practice.

One of the objectives of the present deliverable was to establish a common ground on which the remaining WP1 tasks (T1.4 to T1.5), and later the remaining technical WPs (WP2 to WP4), will build their foundations towards the demonstration (WP5). This work followed a use case-driven approach, starting with the identification of the participating actors and related classification of procedures, the basic use cases, and the evolving to the specification of applicable sub use cases, with specific application scenarios (use case work flow). The Use Cases specified in this final version of the deliverable have been revised since the second version of the Deliverable. By defining a common set of Use Cases, this deliverable D1.2 lays the foundation for the application environment of the SatisFactory architecture and the basic procedures as conducted at each shop floor.

The analysis presented for each Use Case involves application scenarios and system's functionalities usage. Also the interrelation among collaborating actors and correlation with shop floor procedures and key system requirements are presented. The integration of all these has been performed during the deployment phase, which is still on-going, for the developers and integrators to demonstrate the innovative functions of SatisFactory in terms of workers wellbeing, comfort and efficient productivity gains.

From the point of view of the work to be carried out in the future by the several WPs, the specification of application scenarios, use cases and procedures is significant and the results from this task have been as input to subsequent activities of the project. In general, the results included in this document have been utilized in the next steps of the project having a very significant role.

REFERENCES

- EFFRA, *Factories Of the Future - Multi -annual roadmap for the contractual PPP under Horizon 2020*, European Union, 2013
- INDUSTRIE 4.0, <http://www.bmbf.de/>, <http://www.hightech-strategie.de/>
- SMLC, *Smart Manufacturing Leadership Coalition*, <https://smartmanufacturingcoalition.org/>
- Cockburn Alistair, 'Writing Effective Use Cases', Ed. Addison-Wesley Professional, Pearson Education, 2000
- BS EN 13460:2002 Maintenance – Documents for maintenance
- EN 13306:2001: Maintenance terminology
- Havey, M. (2005). *Essential Business Process Modeling*. O'Reilly Media.
- Holt, J. (2009). *A Pragmatic Guide to Business Process Modelling*. British Computer Society.
- Jorge Cardoso, W. v. (2009). Handbook of Research on Business Process Management.
- Marlon Dumas, A. H. (2001). UML Activity Diagrams as a Workflow Specification Language. <<UML>> 2001 — *The Unified Modeling Language. Modeling Languages, Concepts, and Tools*, (pp. 76-90).
- Object Management Group. (2008, 17 01). *Object Management Group*. Retrieved from Object Management Group: <http://www.omg.org/spec/BPMN/1.1/PDF>
- Object Management Group. (2011, 01 03). *Object Management Group*. Retrieved from Object Management Group: <http://www.omg.org/spec/BPMN/2.0/PDF>
- Russell, N. v. (2006). On the suitability of UML 2.0 activity diagrams for business process modeling. *Proceedings of the 3rd Asia-Pacific Conference on Conceptual Modelling*, (pp. 95-104).
- van der Aalst, W. t. (2003). Business process., (p. 12).
- Robert K. Paasch, <http://web.engr.oregonstate.edu/~paasch/48796.pdf>
- SOP, Standard Operating Procedures, <http://www.sop-standard-operating-procedure.com/>
- MIMOSA- An Operations and Maintenance Information Open System Alliance, <http://www.mimosa.org/mimosa-osa-eai>

ANNEX 1 – DETAILED MAIN FLOW OF APPLICATION SCENARIOS

Table 72 COMAU BSC-1.1 Detailed Main Flow - Robot Wrist Assembly

BSC-1.1	Detailed Main Flow - Robot Wrist Assembly
Cleaning of the mechanical parts coming from foundry/machining	Mechanical parts come from foundry or machining and they require some finishing before mechanical installation. These operations have to be performed manually in order to check either mechanical tolerance or overall quality of the component before its assembly.
Gears, bearings and spacers assembly	Gears, bearings and spacers have to be installed inside the wrist housing in the correct order according to the mounting procedure developed from the engineering department.
Sealing and grease filling	Once the former parts are installed within the wrist housing, the external surface has to be cleaned in order to spread the sealing and close the gear housing with its cover. Now the operator has to wait the required time for sealing to dry, thus he can fill the gear box with grease.
Test of tolerances & mechanical couplings	A test of mechanical tolerances and couplings has to be performed on the wrist according to design requirements. In this phase a predefined checklist for quality assurance has to be filled by the operator together with measurements results.
Finally marking electrical motors & wiring assembly	Finally, the electrical motors are installed and the required wirings are placed in position. Furthermore all bolts are checked and marked.

Table 73 COMAU BSC-1.2 Detailed Main Flow - Welding Gun Body Assembly

BSC-1.2	Detailed Main Flow - Welding Gun Body Assembly
Cleaning of the mechanical parts coming from machining	Mechanical parts come from foundry or machining and they require some finishing before mechanical installation. These operations have to be performed manually in order to check either mechanical tolerance or overall quality of the component before its assembly.
Welding gun body-sides assembly	Assemble lateral plates together with bottom reinforcement through M8 screws

Upper reinforcement	Install upper reinforcement to keep the lateral plates in position in the upper part of the welding gun
Fulcrum installation	Install the central fulcrum
Spacers	Install the spacers using the centering gage to find the right position of each spacer
Motor pin	Install motor pin
Bolts tightening and marking	Tighten at the bolts at the correct torque through the specific tools and mark their positioning for future verifications

Table 74 SUNLIGHT BSC-3.1 Detailed Main Flow –Preventive and corrective maintenance management system

BSC-3.1	Detailed Main Flow –Preventive and corrective maintenance management system
Definition of the malfunction incident	The maintenance manager receives the information about the needed maintenance. He makes a plan with the required actions.
Action planning	The maintenance manager prioritizes the open incidents. He verifies the availability of the spare parts, tools and manpower and designs an action plan.
Work scheduling	The maintenance manager assigns the work to be done to the technicians according to the action plan.
Work assignment	The technician receives at the tablets, smart phones or glasses all the information that they need to perform the corrective work. They will be able to chat with the manager while working and get any additional information that they may need.
Work execution	The work is executed by the technicians according to the given instructions. Any unexpected difficulty is reported to the manager for additional advises.
Work completion	The technicians, after finishing the action, they perform verification that the operation has been restored successfully.
Production of Reports	The maintenance manager creates a report, providing a detailed description about the taken actions. The details are stored in a database and all the information is available online by the technicians and the maintenance manager.

Table 75 SUNLIGHT BSC- 4.1 Detailed Main Flow - Motive power battery assembly line

BSC- 4.1	Detailed Main Flow - Motive power battery assembly line
Definition of the Production Order	<p>The supervisor who is responsible to run the weekly production schedule will prioritize the work orders that will be executed next.</p> <p>The system will be able to identify the type of battery that will be assembled next and provide to the workers all the necessary information about each particular work order such as order number, product id, customer id, etc.</p>
Provision of the required drawings or working instructions	For each battery type there are particular drawings and instructions providing the battery cell placement order or the battery cells connections. This information is available at the local working station through an HMI. The system will provide automatically this information based on the product id number and display the drawings or assembly information on the wall screen and tablets.
Work Scheduling	After receiving all the necessary information, the system will reserve the time slot to perform the battery assembly.
Battery assembly execution	<p>Motive power batteries are assembled manually. Works are carried out according to the assembly instructions and the technical information provided by the system.</p> <p>The assembly process can be divided in six stages:</p> <p>In the first stage, a worker places the battery cells in the metallic box. The placing order is specified by the relevant drawing.</p> <p>As a second stage, the battery cells must be connected in series by using appropriate intercell connectors. A worker connects the intercell connectors to the battery poles using the appropriate bolts.</p> <p>In the third stage, a worker adjusts the electrolyte level in each battery cell and then the battery cells are sealed by using either regular plugs or automatic water filling plugs.</p> <p>In the fourth stage, a worker installs the output plugs of the battery and the external labelling of the battery.</p> <p>In every stage, the worker can point the scanner to the barcode on a part to check if that part is the one referred to in the assembly instructions</p>
Quality control	In the next stage a worker performs quality control of the final product. He performs a cross-check that the battery has been assembled according to the provided technical information and assembly instructions. The worker creates a Q.C. report. After that the battery is ready for packing
Labelling and packing	In the last stage a worker does the labelling and the packing of the final product.
Customer order completion	The foreman informs the system that this particular work order is completed and makes the order available for pick up.

Table 76 SUNLIGHT BSC-4.2 Detailed Main Flow - Monitoring of the Cell Temperature during Jar formation and data collection

BSC-4.2	Detailed Main Flow - Monitoring of the Cell Temperature during Jar formation and data collection
Identification of the abnormal situation	Identify the battery cell which has an abnormal temperature increment during the jar formation process. This identification is possible by scanning the batteries, which are connected to the jar formation modules, with the thermal camera.
Alarm recognition	The system provides a real time alarm to the production supervisor who is in charge in each shift. The alarm will appear in a context aware tablet, the screen or the glasses.
Alarm acknowledgment	The production supervisor acknowledges the alarm through the tablet and request more information. The SatisFactory system will provide the identification number of the jar formation module or/and the thermal camera. By receiving this information, the exact location of the incident will be determined. Additional information such as action plan and working direction will be available on the screen.
Work assignment	The production supervisor will assign the case to the available worker in order to take immediate action according to the provided action plan.
Work execution	The Jar formation process will be interrupted to this particular string and the overheated cell will be investigated by the worker. The failure will be restored and the formation process will be continued. Historical data of all actions will be recorded.
Work completion	The behaviour of the failed string will be monitored in order to verify that the problem has been restored.
Production of Reports	The incident will be logged by the system. The production supervisor will create a report with the performed actions.

Table 77 SUNLIGHT BSC-4.3 Detailed Main Flow - Training platform for motive power batteries assembly line

BSC-4.3	Detailed Main Flow - Training platform for motive power batteries assembly line
Identification of training needs	The foreman identifies whether the worker needs training or not. In principle, training is needed to the new workers or to those that are moving to several working positions.
Determination of training field	Motive batteries assembly line has six stages. New workers should be attending a dedicated training for their working position. Workers that are moved to several working positions will attend the relevant working courses.

Implementation of the training	Training courses will be available in tablets. Each course will include the relevant technical knowledge and safety instructions, with a demonstration or guidelines on how to use the safety equipment. Trainees will get a general technical background about the specific products and then a step by step description about the particular assembly procedure. Trainees will be able to interrupt the process and move the training courses back or forward for better understanding.
Evaluation of the training	Once the training course is finished, it will be an option to perform a theoretical knowledge test. The training platform will include multiple choice questions broadly related to the factory and also containing questions for each one of the courses.
Training in the workplace	The training platform will include the ability to perform training to each one of the workplaces. Training in the workplace will incorporate AR devices which will show to the trainee how to do the assembly. The trainee will be able to repeat the course if it is necessary.
Provision of the training information	All the training information for both theoretical and practical courses will be available in the workplaces providing assistance to the workers. The information can be displayed in a wall screen or in a tablet.

Table 78 CERTH BSC-5.1 Detailed Main Flow - Replacement of a malfunctioning heating resistance

BSC-5.1	Detailed Main Flow - Replacement of a malfunctioning heating resistance
Task collection and Definition	The automation system indicates at the monitoring HMIs that the output of the controller remains at 100% although the temperature does not increase to the desired set-point values. The process operator observes the respective panel dials and indications of the temperature fluctuation. He informs the maintenance manager that a potential problem has occurred at a heating resistance of the specific zone of the reactors and he performs a severity estimation of the problem.
Work Planning – Design of the work	In case the process is in fully operational mode and not in start-up the incident is assigned a high priority. The standby maintenance technician is informed and immediately proceeds to the process unit in order to verify the process operator observation in conjunction with the indication from the control system of the unit. The technician performs an initial tracing of the problem and determines the equipment and tools that will be used (e.g. Voltammeter fuses etc.) The process operator checks the historical data of the specific part and of similar malfunctions.
Work Scheduling	The immediate corrective actions are given a high priority compared to the nominally scheduled actions and the work schedule is updated by adding the newly appeared problem. The maintenance dashboard is automatically updated and the maintenance manager informs the process manager about the estimated time for the repair actions.
Release – Assignment of the Work Order	The respective electrical and automation technician are assigned to the new case and proceed to the process unit.

Execution - Carry Out the Work	The electrical technician and the automation technician are informed from the context aware tablet about the specific parts that need replacement. More specifically, they check the electrical schematics to test the fuse status while the process operator turns to manual and zero output the controller. In case the fuse is operational the electrical technician checks the inventory for a spare heating resistance using online information from the Electrical BOM list, fetches the new one, disconnects the faulty one to prevent potential short-circuit to the system and updates the spare parts list. The Glasses indicate the specific place where the resistance is connected. Also in case there is an insulation layer the Glasses capture the connecting points of the existing insulation and the metal cases. The process operator receives information about the extent of the zones that need to close to reduce the heat. The Glasses and the context aware tablets indicate that the temperature is reduced at the specific point of interest, the process technician removes the insulation and the electrical technician proceeds to the replacement of the resistance. The process temperature is restored as soon as the electrical technician indicates that the work has been completed through the on-site tablet. Both the process manager and the maintenance manager are informed about the outcome of the performed actions.
Closure of the work order	The automation technician checks within the SCADA software that the operation responds as documented and that the problem that caused the replacement has disappeared. He also verifies that the normal operation remains after a period of time and informs all the involved actors the he has finished. After that the technicians record the working hours spent for solving the problem.
Production of Reports	<p>The system creates reports about the duration of the maintenance and the manpower used. A list of all parts that were used is also created. The process supervisor is able to view the maintenance history as well as the possible reason of the malfunction at the intuitive HMIs.</p> <p>The maintenance supervisor compares the resources being used for the completion of the procedure with similar cases exported from the database. He makes proposals that could improve the maintenance procedure and suggests whether there are new equipment or other parts that could be more sufficient regarding the existing structure.</p>

Table 79 CETH BSC-5.2 Detailed Main Flow - Start-up procedures of VB01 Hydrocracking pilot plant

BSC-5.2	Detailed Main Flow - Start-up procedures of VB01 Hydrocracking pilot plant
Task collection and Definition	Process operators along with the process supervisor are advised using the user's manual and the safety manual of the shop floor to decide the necessary tasks/actions and to see if there should be any changes from the written procedures (according the needs of the upcoming experiment).
Work Planning – Design of the work	The process supervisor categorizes the actions and gives guides to process operators (through tablets) about the workflow of the procedures. He creates the work order list.

Work Scheduling	The process supervisor sends a query (via tablet) to the maintenance supervisor to inform him for the needed actions. The maintenance supervisor must make sure that the necessary parts are available and reserve the manpower (process technicians) that will perform the startup procedures along with the process operators.
Release – Assignment of the Work Order	The maintenance supervisor assigns the needed tasks (according to the work order list) to process technicians
Execution - Carry Out the Work	<p>Process operators will prepare the feedstock material to be loaded in the feed tank according to the experimental requirements that will be defined by the process supervisor. The process operator will start the pump that will be used to load the feedstock in the tank as well as heat the feedstock lines to temperatures set by the process supervisor for maintain the feedstock flow properties according to its quality. Prior to start feeding the feedstock to the feed tank, the process operator will calibrate the scale in order to accurately indicate the loaded weight of the feed that will be loaded.</p> <p>The whole procedure is being displayed (step by step) at the context aware tablets.</p>
Closure of the work order	Several steps of cleaning all auxiliary lines will also be performed by the process operator.
Production of Reports	<p>The system creates reports about the performed actions and their effect.</p> <p>The maintenance supervisor records the man-hours that needed, updates the dashboard for the closure of the work and changes the status of the involved technicians to available.</p> <p>The process supervisor analyses the results of the tests and compares them with previous. He records if any hardware failures or human mistakes came up during the procedure.</p>

Table 80 CERTH BSC-5.3 Detailed Main Flow - Switching pilot plant operation from methane steam reforming to ethane oxidative dehydration

BSC-5.3	Detailed Main Flow - Switching pilot plant operation from methane steam reforming to ethane oxidative dehydration
Task collection and Definition	The process supervisor updates the Dashboard with the plan of the new experiment, which requires switching the operation of the pilot plant. One new task recorded as scheduled maintenance. Afterwards, he informs involved actors and proceeds on planning the actions.

Work Planning – Design of the work	<p>A list of the required parts, for switching the operation of the pilot plant, is automatically created based on the flows and the type of gas that will be used, specified by the process supervisor.</p> <p>The process supervisor makes groups with long term and short term tasks in order to give priorities. The required tasks are based on the operation manual of the pilot plant for the transition from one process to another.</p> <p>The process supervisor categorizes the actions and gives guides to the process operators about the workflow of the procedures. He creates the work order list.</p>
Work Scheduling	<p>The process supervisor contacts the maintenance supervisor to inform him for the needed actions. The long-time tasks are given priority. The maintenance supervisor must make sure that the necessary parts and tools are available and reserve the manpower (process and electrical technicians). He gives priority to the long lasting tasks.</p>
Release – Assignment of the Work Order	<p>The maintenance supervisor assigns the needed tasks (according to the work order list) to the involved technicians.</p>
Execution - Carry Out the Work	<p>The process technician replaces the mass flow controllers with bigger or lower flow devices. The control technician calibrates the new mass flows and updates the new ranges in the HMI Database. The process technician mounts the appropriate gas bottles and the new mass flows. The process operator changes the valves based on the documentation of the new process. The control technician switches the I/O signals (e.g. Temperatures) of the automation system which are used in both pilot plant operations in different places. Then he updates the alarms of the HMI. The process operator changes method on the chromatograph and checks the reliability of the method.</p> <p>All the procedures are being displayed (step by step) at the context aware tablets and at the intuitive HMIs. By activating the augmented reality mode, the process operator can view the new process flow which is visualized for him in a way that the virtual information is displayed aligned with the physical environment he currently sees.</p>
Closure of the work order	<p>The process technician links the reactor to helium bottles in order to perform a pressure test tracing possible leaks before the reactor be placed to the pilot plant. After that the process operator checks if all the requirements of the new operation are fulfilled.</p>
Production of Reports	<p>The process supervisor analyses the results of the tests and compares them with previous. He records if any hardware failures or human mistakes came up during the procedure.</p> <p>The maintenance supervisor records the man-hours that needed to full the procedure and creates reports that will be given to the process supervisor.</p>

Table 81 CERTH BSC-6.1 Detailed Main Flow - Accident prevention of workers inside the shop floor area

BSC-6.1	Detailed Main Flow - Accident prevention of workers inside the shop floor area
----------------	---

Task collection and Definition	The system is communicating with the depth cameras and is collecting all the data being sent.
Work Planning – Design of the work	The system identifies every movement of the workers. It evaluates any possible danger according to the imported to it data from the shop floor. These data are: the location of the pilot plants, the exact schematics of the shop floor, the possible places that human entrance is forbidden or should be very carefully, possible temporary changes of equipment position (e.g. for a planned maintenance).
Work Scheduling	The system is always ready to identify any possible danger and to start the appropriate procedures
Execution - Carry Out the Work	The system identifies upcoming accident and informs the worker. It sends notifications to his glasses and context aware tablet. It also notifies the Maintenance supervisor and the Process supervisor (according to the exact location of the possible accident) and sends a message to the intuitive HMIs. In case of no positive feedback the system sounds the alarm of the shop floor to alert all workers in order to prevent the upcoming accident
Closure of the work order	After the corrective actions from the worker's side, the system receives new data that ends the possibility of danger. The system turns off any alarm that had triggered and sends notifications to the intuitive HMIs, the context aware tablets and the glasses that the danger has overcome and is safe to return to the normal operation
Production of Reports	<p>The maintenance manager must create reports with the taken actions. He can also study all the incidents (with taken or not actions) and suggest new procedures in order to improve the reaction of the system and the ability to identify and prevent accidents.</p> <p>The floor manager has the overall control and cooperates with the maintenance manager for improving the system.</p>

Table 82 Alternative Detailed Main Flow - Accident prevention of workers inside the shop floor area

BSC-6.1	Alternate detailed Main Flow - Accident prevention of workers inside the shop floor
Task collection and Definition	The system is communicating with the UWB devices (or the SSN) and is collecting all real-time data being sent.
Work Planning – Design of the work	The system identifies the position of workers at the shop floor and detects whether they enter or go out from a forbidden/dangerous area. In order to have a robustness sensing infrastructure, the system is able to assess the quality of the wireless channel while it collects environmental sensors data. The dependable network is able to reduce the impact of noisy channels and increase the quality of communication services by selecting the best available technology. The system generates alerts when a worker is inside in one of the forbidden areas (previously defined by the safety manager). The data to be taken into account are: the location of the pilot plants, the map of the shop floor, the forbidden areas, the exact location of the UWB anchor devices deployed on the shop floor and the workers' UWB ID.

Work Scheduling	The system is always ready to identify any potential danger and to start the appropriate procedures.
Execution - Carry Out the Work	The system identifies any potential accidents based on the virtual fencing logic and alerts the worker. It sends notifications to either his context aware tablet or his glasses. It also notifies to the closest maintenance supervisor and the process supervisor and sends a message to their intuitive HMIs. In case of no positive feedback, the system will activate the acoustic alarm of the shop floor to alert all workers in order to prevent any potential accident.
Closure of the work order	When the corrective actions from the worker's side are taken, the system turns off the potential danger alert. Moreover, the system turns off any alarm that had triggered and sends notifications to the intuitive HMIs, the context aware tablets and the glasses notifying that the danger has overcome and it is safe to return to the normal operation.
Production of Reports	<p>The maintenance manager must create reports with the taken actions. He can also analyse all the incidents alerts (with taken or not taken actions) and suggest new procedures in order to improve the reaction of the system and the ability to identify and prevent accidents.</p> <p>The floor manager has the overall control and cooperates with the maintenance manager for improving the system.</p>

ANNEX 2 – REQUIREMENTS DESCRIPTION

Req. #	SAFA #	Summary
1	4	The HMIs of the platform shall be attractive and easy to use
2	13	The tools and applications must be 24/7 operational
3	17	The tools shall be able to successfully exchange data with the existing infrastructure at the shop floors
4	18	SatisFactory tools shall give detailed description of selected maintenance actions
5	19	The platform will include a personal protection equipment usage reminder
6	24	SatisFactory components must have a successful and continuous data exchange with CIDEM
7	27	Accurate detection of incidents
8	31	Successful integration of all heterogeneous devices of the shop floors
9	32	Standard Operating Procedures (SOP) shall be provided to the workers
10	33	The platform of SatisFactory must enhance remote support and maintenance for the shop floors
11	34	The system shall be able to monitoring actors through privacy preserving sensors
12	37	The platform should present training procedures through multimedia content
13	40	Depending on the SOP, some steps of the training activity shall be automatically verified
14	41	All shop floor data must be stored in a common database
15	55	The system shall be able to detect both pro-active and re-active incidents at the shop floor
16	58	The AR components of SatisFactory must have continuous access to the database
17	59	The platform shall support social communication between actors
18	62	Gamification tools will be interactive with the actors
19	65	AR tools will have the ability to interpret the displaying operating procedures
20	66	Multi-Layered Description of Operating Procedures (OP-MLD) Realtime Ready
21	67	The platform will allow uncoupling of Multi-Layered Description of operating procedures and their Interactive Realtime Visualization
22	69	The symbols/terminology of the data presented on the glasses must be effective and easy to understand
23	73	Continuous and successful data transfer between glasses and the the database of each shop floor
24	75	The frame of the glasses shall be optimal for the workers
25	76	Real time and continuous monitoring of battery cell temperature during the procedure of Jar formation
26	79	Real-time incident detection during Jar formation of batteries' cells
27	93	Alarms shall be accompanied with a description
28	101	Different opinions shall be exchanged during the operation of a task
29	105	The system shall provide means of submitting suggestions for improvements available, in order to contribute to modernisation and overall improvement of

		working conditions
30	107	The system shall utilize skills and capabilities of the workers available for optimal work assignment
31	108	The system shall improve teamwork through optimal task allocation
32	117	The system shall support inter-change of best practices between departments and units
33	118	The product shall provide means to teach co-workers
34	120	The communication product shall be open for non work related content
35	131	Competition shall be informal and friendly
36	132	The product shall not restrict workers' autonomy
37	133	The system shall have access to the most recent work schedules
38	134	The system shall be able to be adapted to different shifts
39	135	The system shall not influence workers' carefulness
40	136	The system shall be applicable when workers wear a mask
41	137	Support flexible deviations from plan
42	140	Support mobile users
43	143	Support feedback answers on suggestions for improvement
44	146	Release answers/feedback on suggestions for improvements to operators
45	148	Human-Resources toolkit shall efficient manage idle times
46	149	The system should be able to manage all the open tasks
47	154	Continuous access to training procedures
48	171	All tasks should have priority and criticality ranks
49	172	The system shall be able to combine the heterogeneous acquired data from the shop floor
50	174	Continuous update of the operators' skills
51	176	The system shall provide efficient means for instructing workers on the necessary assembly parts of a battery belonging to an order and necessary actions at each step of the assembly procedure
52	178	Installation and troubleshooting of the system shall not require training beyond IT network administration and maintenance
53	181	No frequencies, physical media, and protocols will be used for communication that interfere with existing communication systems at the factory
54	184	The connectors, screws, and other electromechanical elements of the system shall match with the standard types used in the country where the factory is located
55	186	The measurement units for the dimensions of the parts of the system shall match the units common in the deployment country
56	187	Measurements, events, logs, and all shop floor dynamic shall be in the time zone of the deployment country
57	189	HMI tool (on Mobile device) could be used to take photos from the working area
58	192	Association of the workers' names with their suggestions
59	193	Time duration availability of the suggestions
60	197	UIs shall be in the formal language of the deployment country
61	198	All UI interaction parts should be clearly visible
62	200	The UIs should be user-friendly

63	202	Suggestions will be sorted by submission date
64	203	Suggestions filtering support
65	204	Personal statistics available to the users
66	205	Evaluation of a contribution will support point scale
67	206	The product shall keep the prize detail separate from the system
68	207	Suggestions system should support suggestion categories
69	208	Open suggestions shall be sent to the decision makers
70	211	The suggestion submission form shall be in similar format as the preexisting manual system
71	215	Gamification must be presented in several subcomponents of satisfactory
72	217	The gamification framework must support PBL
73	218	No participant of the gamification shall be exposed as loser
74	220	Other SatisFactory components shall submit points of participants to the gamification framework
75	221	The gamification framework should allow workers to participate individually as well as in teams
76	222	All urgent tasks shall be properly allocated to the employees
77	223	Current location of employee shall be taken into account by the RA & HR workload balancing tool
78	224	The system should be able to interface existing measurement tools and infrastructure
79	225	All historical data from the shop-floor shall be available through CIDEM
80	226	All information exchanged and stored within SatisFactory components shall be in a common format understandable from all components
81	227	Timely workers notification in case of an alarm
82	228	The UI shall provide maps visualization for a more concrete understanding
83	229	The messages provided by the system shall be clear and easy to understand
84	230	The SatisFactory components shall be able to store and retrieve large amounts of data
85	231	In case one or more components are not reachable on the network, the system shall be able to manage the whole operation without them and their data
86	232	Communication among SatisFactory components will be platform independent

ANNEX 3 – DESCRIPTION OF THE ARCHITECTURE COMPONENTS

Smart Sensor Network

Dependable Network Infrastructure

This component comprises wireless networks of IoT devices, featuring robust connectivity for delivering relevant data and events across the shop-floor. This component is essential for providing the necessary information to the SatisFactory knowledge-base and thereby enable context aware applications.

Ultra Wide Band (UWB) Localization Devices

The Ultra Wide Band (UWB) Localization Devices can be of three types (i.e., tag, anchor and gateway) and are used in indoor environments to provide location information. Typically, the anchors are placed in fix and well know positions in the region of interest. The tags are worn by workers and/or installed on mobile objects whose positions need to be estimated. During the estimation process the tags continuously interact with anchors. In particular, each tag performs range measurements with respect to the anchors that are in the connectivity range. After that, a localization algorithm, which runs on the tag itself, uses range measurements and anchor positions to estimate the tag's position. Finally, the gateway is the end-point of the localization devices; it receives localization data from tags and forwards them to the Localization Manager through the Middleware by using a serial interface

Depth Sensor Network

The depth sensor network is responsible for providing to the system privacy preserving information from depth cameras/sensors to the system. This information will be mainly focused on the analysed of the human movements and actions in the shop-floor.

Thermal Sensor Network

The subcomponent is responsible for providing to the system privacy preserving information from thermal cameras/sensors to the system. This information will be mainly focused on the analysed of the human movements and actions in the shop-floor, as well as to the detection of reactive incidents, such as sudden increase of temperature.

Automation Systems - I/O Field Network

The existing automation systems and the input/output (I/O) network of sensors are responsible for acquiring data from the shop floor field (legacy and existing smart sensors/devices) and to present it to transmit it to the workers through the existing Human Machine Interfaces (HMIs). The acquired information from the I/O field will be send to the repository and the integrated DSS. Besides the measurements, the automation systems transmit information about events and alarms of the involved systems.

Middleware

Device Manager (DM)

The Device Manager provides the instruments to simplify heterogeneous physical devices virtualization through common interfaces. These devices have different capabilities, communication technologies and features. A device virtualization is needed to help the seamlessly integration of



these devices with other SatisFactory components and features (e.g. DSS systems, Semantic Context Manager, etc.).

Event Manager

This component provides publisher-subscribe based notification mechanism to other SatisFactory components and services. Mainly the data captured from smart and other sensor types are collected processed and store in a repository through the Event Manager.

Semantic Context Manager

Ontology Manager

The Ontology Manager is a tool used to manage ontologies of SatisFactory. It can be used to list ontologies of SatisFactory, to create/import new ones, to delete existing ones, to generate underlying ontological structures.

Localization Manager

The Localization Manager provides as output location information of objects and workers given as input the identifier of the associated UWB devices. This module receives either ranging or localization data from the UWB modules through the middleware. Moreover, it provides geo-fencing events when a worker approaches a forbidden area.

Multimedia Manager

The Multimedia Manager is a component responsible of handling information concerning video streams. If necessary and required, the video can propagate contextual information as metadata embedded in the video streams. Privacy preservation is also in scope of this component, where required.

Gesture & Content Recognition Manager

The Gesture & Content Recognition Manager is a component in charge of performing a complex set of analysis on input streams and it reacts to a certain level of configurable alerts, triggering context aware events. The component works under the assumption that the background can be mapped and this mapping action can be performed with regular scheduling.

Collaborative Tools

Social Interaction and Cooperation

The Social Interaction and Cooperation component provides a platform that workers can use to interact with their (remote) colleagues. It can be used to cooperate on work related issues, e.g., requesting for help for a particular problem or for sharing off-topic interests.

Gamified Process Support

The gamified process support primarily integrates concepts that are typically known from games into work processes. Alternatively new processes can be created.

Integrated DSS

Maintenance Procedures

Maintenance Procedures followed on the shop floor represent a considerable workload for the examined actors in the use cases of the SatisFactory project, as well as in use cases anticipated in



industrial manufacturing factories. The steps followed to perform the procedures involve the usage of SatisFactory components.

Shop floor Feedback Engine

The detected incidents will be paired with the corresponding response procedures, in order to give feedback to the shop floor in terms of actionable knowledge and recommendations, in cooperation with the DSS module.

Incident Management Tools

The subcomponent represents a substantial role in the everyday activities of actors involved in Use Cases in all pilot demonstrations supporting workers' safety and comfort. The main goal of the module is the detection of proactive and reactive incidents on the shop floor. The system detects and alerts the possibility of a risky condition (proactive incident) and incidents after their occurrence (reactive) based on real-time data. In both cases, the tool performs the corresponding predefined countermeasures.

Maintenance Toolkit

The subcomponent represents a substantial role in the everyday activities of actors involved in Use Cases in all pilot demonstrations. Modules include asset register, corrective and predictive maintenance, condition-based maintenance, scheduling and implementation of work orders, setting approval limits and spare parts procurement rules etc.

Production Activities Tools

The subcomponent will be responsible to check the dynamic information from production activities, so as to detect the operating status of production line. If a part of the production line is broken (has been stopped working properly) or presents underperformance, then an alarm will be sent to the integrated DSS.

Real-time Analytics Module

The real-time analytics module is responsible for correlating, combining and analysing heterogeneous data acquired from the smart sensor network in order to evaluate the shop-floor and production operations, supporting comparative assessment of worker's situation and suggesting role-based actions.

Visual Analytics Module

The subcomponent presents different state-related views of the supervised shop floor. It will provide the capability to compare and assess the situation of the workers in a visual and comprehensive way taking into account properties of human cognition, perception and sense making. It will combine, correlate and visualize large, complex and heterogeneous data providing a multi-factorial exploration in the spatio-temporal domain, assisting end-users/managers to detect patterns, templates and crucial points that are difficult detected otherwise.

AR In-Factory Platform

Gamification Augmented Reality

This component cannot be identified with a single module, tool or API. Instead it defines the way in which AR Presentation Tools are implemented. They can be easily customized and adapted to needs of specific final users and support gamification in order to increase their engagement. Gamification is based not only on attractive interfaces but also on specific scheme, user interaction and activity evaluation and scores.

SOP & Content Data Enrichment Tools

Data Enrichment Tools allow to associate specific “Semantics” to source data (e.g. 3D models, images, videos, documental data, etc.), typically linked by the description of Standard Operating Procedures (SOP). This enrichment allows to accelerate the creation of AR SOP (Augmented Reality Standard Operating Procedure) presented afterwards by the AR Presentation Tools and feeding both Training and In-Factory environments. For instance by having semantically enriched 3D models, it is possible to automatize the creation of 3D animations of components involved in a specific user activity. The final “enriched data”, that maintain “just linked” the source data without changing them, can be directly saved into the SatisFactory Repository in order to be accessed both by the AR SOP Creation Tools and the AR Presentation Tools during a runtime session in the shop floor or in the training area.

AR SOP Creation Tools

The Creation Tools allow converting original Standard Operating Procedures, often described with different formalisms, in a new format, called AR SOP (Augment Reality Standard Operating Procedure) ready to be used by the AR Presentation Tools developed to support both training and operational environments. The Creation Tools provide functionalities designed to describe a new AR SOP both manually in an offline context and by an “on the job” approach. Latter is directly based on specific sensors (e.g. motion tracking systems) placed in the work and/or training areas, that can capture the operator’s activity and recognize objects, components and tools.

The tools themselves support the technical actor who is in charge of the new AR SOP creation, by providing him power wizards, semantically enriched data management, UI based on a visual language and a lot of automatically generated contents (e.g. 3D animations, video clip, synthesized speech, etc.).

AR SOP Presentation Tools “On the Job”

The Presentation Tools provide a rich set of visualization and interaction functionalities in order to present previously prepared AR SOP directly “on the job”. By using these tools, operators can follow a specific procedure step by step, obtain support for their current task and choose which kind of information and which level of detail they want about the procedure. Moreover the tools themselves can become a “view channel” to show relevant information available at runtime from Middleware, Integrated DSS and Event Manager Modules. Key features of the Presentation Tools are: a) different target platforms support (e.g. Windows and Android); b) high scalability on physical devices (e.g. desktop pc, mobile devices, wearable devices); c) large number of presentation modes (e.g. in Augmented Reality, Virtual Reality, Speech only, Text only, hybrid, etc.).

AR SOP Presentation Tools in Simulated Framework

The Presentation Tools provide a rich set of visualization and interaction functionalities in order to present previously prepared AR SOP in a Simulated Framework. By using these tools, operators can follow a specific procedure step by step, obtain support for their current task and choose which kind of information and which level of detail they want about the procedure. Moreover the tools themselves can become a “view channel” to show relevant information available at runtime from Middleware, Integrated DSS and Event Manager Modules. Key features of these tools are: a) different target platforms support (e.g. Windows and Android SO); b) high scalability on physical devices (e.g. desktop pc, mobile devices, wearable devices); c) large number of presentation modes (e.g. in Augmented Reality, Virtual Reality, Speech only, Text only, hybrid, etc.).

Repository

Incident Related Dynamic & Persistent Data

The subcomponent refers to models for the data related to incidents in the shop-floor. The data will contain both static (e.g. building geometry, etc.) and dynamic information (e.g. human movements, etc.) of the shop-floor and the incident that happened or may happen.

Asset-Machinery-Production Data

The subcomponent refers to data related to assets, machinery and production. The data will be grouped following the hierarchy of the machinery components, subcomponents and topology, as well as the associations with the production activities.

Asset-Machinery-Production Models

The subcomponent refers to models for the data related to assets, machinery and production. The data will be grouped following the hierarchy of the machinery components, subcomponents and topology, as well as the associations with the production activities.

Operational Platform with Augmented Intelligence

Operational Platform with Augmented Intelligence

It is responsible for providing real-time diagnostics and control actions to the operators at nominal conditions of shop floor operation. The platform communicates directly with the middleware component and the DSS system in order to derive the optimum actions based on the current state of the machines and the worker's behaviour. It is responsible for providing an overview of KPIs, personalized notes and tasks that are adjusted per worker. Additionally AR platform will integrate and present the Semantic Context and the Collaborative tools through an easy to use and intuitive interface.

Training Educational Platform

On the job Training & Educational Tools

The Training & Educational Tools provide a further specialization on AR SOP Presentation Tools in order to include the typical human interaction between the actors involved in a training and educational session (e.g. teacher-trainee, supervisor-worker, experienced-beginner). The tools allow training "on the job" and can manage both manufacturing and maintenance procedures. Training tools make use of all functionalities already implemented in the AR In-Factory Platform Tools, both for the creation and for the presentation of the procedures. Moreover training tools take more closely in account specific Use Cases and role based environments.

Training in Manufacturing Procedures for Maintenance

The subcomponent plays a critical role in the improvement of the satisfaction of workers. In all Manufacturing Procedures addressing the necessity for maintenance of physical assets is essential. To do so, well-trained workers are needed. The subcomponent works using collaboratively the tools developed, focusing on the use of HMIs and AR devices.

Multi modal & Augmented HMIs and AR devices

Adaptable user interfaces and interaction techniques



This component provides the user interfaces and interaction techniques that are used by workers to access the SatisFactory tools. The user interfaces adapt to the workers' capabilities and context. Novel interfaces and interaction techniques are explored.

Glasses HMI

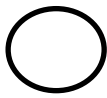
The subcomponent belongs to the main component of Multi-modal & Augmented HMIs and AR devices. Together with other HMI devices of different nature, HMI glasses on one side enable Augmented Realism (AR) services both to real (AR) and virtual environments (VR) for a richer experience. The relative AR platform feeds with augmented information services both the Training Educational Environment and the Operational Platform with Augmented Intelligence

ANNEX 4 – MODELING STANDARDS

Business Process Modelling Notation (BPMN) elements

The BPMN Language consists of four core elements:

Flow objects, which are the nodes of the graph. A flow object must have a type, which can be of activity, *event* or *gateway*.



An event is something that “happens” during the course of a business process. These events affect the flow of the process and usually have a cause (trigger) or an impact (result). Events are circles with open centers to allow internal markers to differentiate different triggers or results. There are three types of Events, based on when they affect the flow: Start, Intermediate, and End.

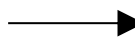


An activity is a generic term for work that company performs. An activity can be atomic or non-atomic (compound). The types of activities that are a part of a Process Model are Process, Sub-Process, and Task. Tasks and Sub-Processes are rounded rectangles. Processes are contained within a Pool.

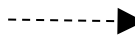


A Gateway is used to control the divergence and convergence of Sequence Flow. Thus, it will determine branching, forking, merging, and joining of paths. Internal Markers will indicate the type of behavior control.

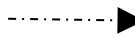
Connecting objects, which are the edges of the graph. A connecting object must have a type, which can be of sequence *flow*, *message flow* or *association*.



A Sequence Flow is used to show the order that activities will be performed in a Process.



A Message Flow is used to show the flow of messages between two participants that are prepared to send and receive them. In BPMN, two separate Pools in a Diagram will represent the two participants (e.g., business entities or business roles).



An Association is used to associate information with Flow Objects. Text and graphical non-Flow Objects can be associated with Flow Objects. An arrowhead on the Association indicates a direction of flow (e.g., data), when appropriate.

Swimlanes, which are used to group other modelling elements. This grouping can be either a pool which represents an entire process as shown in Figure 115, or a lane which is a sub-partition of a process and is used to organize and categorize activities as shown in Figure 116.

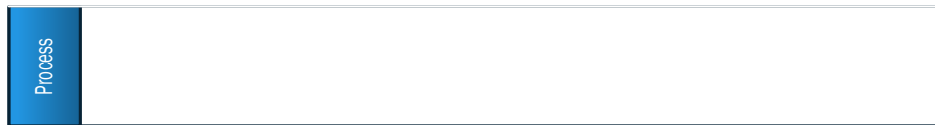


Figure 115: A pool



Figure 116 A Pool with lanes

Artifacts, which are documents, data, etc. They are either required by an activity before it can be performed or they are produced at the end of an activity. An artifact is depicted with the following symbol:



Data

Figure 117 A Data object artifact

BPMN version 2.0 specification which is the current standard version was released to public in January 2011. There is also a Version 2.1 RFC which is only available to Object Management Group (OMG) members at the moment. OMG states that there will be no major rewrite of the standards for the next 2 – 3 years.

Petri Nets Notation

Figure 118 shows a simple Petri Net which is used to model the process of buying a house, just to illustrate the basic components of the standard. The initial state of the process is depicted by the start place, which contains the marker showing the current state. In that state the only transition that can be fired is the one that corresponds to the potential buyer of the house submitting an offer. This is depicted by the transition “Submit offer” which moves the token to the output place of the transition. In the same way the next transition might either be the acceptance of the offer, which then leads to the “Sign Contract” transition and the final termination of the procedure, or the “Offer Rejected” transition which might lead to either the “Improve Offer” or the “Withdraw Offer” transition. In the former case the process repeats from the place which is immediately after the first transition or terminates. In all steps the marker moves to the place that shows the current state of the process. Figure 119 shows the same model after the “Submit Offer” transition has fired.

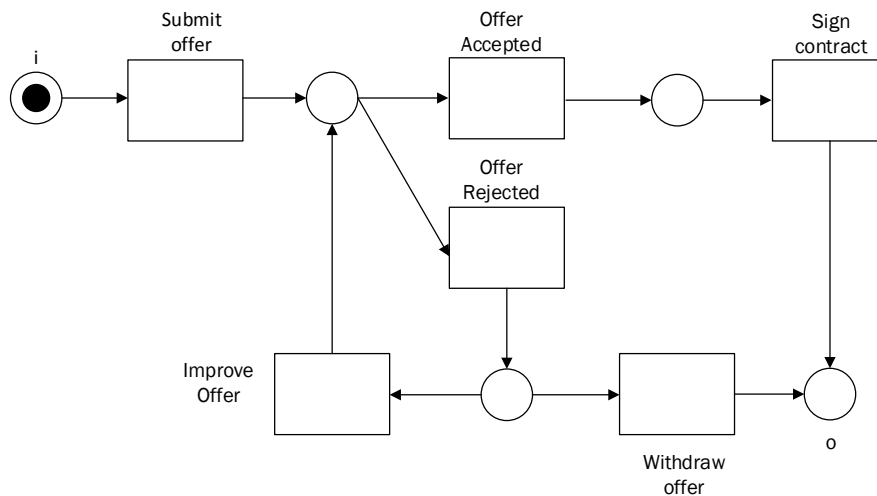


Figure 118 Petri Net modelling a simple process

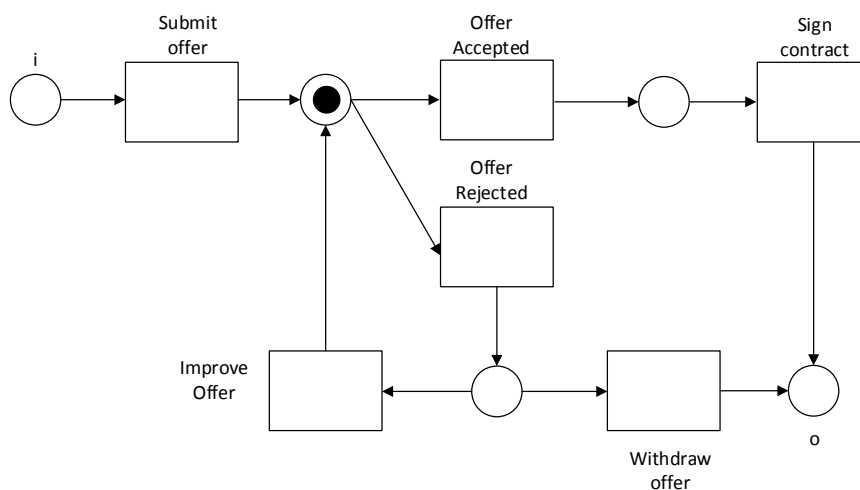
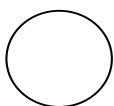


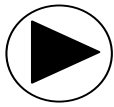
Figure 119 State of the process immediately after “Submit offer” transition fired.

Yet Another Workflow Language (YAWL) Notation

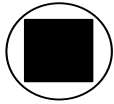
The basic modelling elements of YAWL are the following:



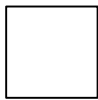
Condition. This element represents the state that a workflow is in, after one task is finished but before the next task begins. Conditions allow us to model two or more participants competing for the same work, or a user making a decision on things that workflow systems cannot automatically determine.



Input Condition. An input condition represents the starting condition of a process or a sub-process of the general process.



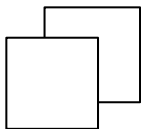
Output Condition. An output condition represents the final condition of a process or a sub process.



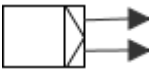
Atomic task. An atomic task corresponds to atomic actions, i.e. actions that are either performed by a user or by a software application.



Composite task. Each composite task refers to a child or sub-net that contains its expansion.



Multiple instances task. A task (either atomic or composite) can have more than one concurrent instance at run-time.



X-OR Split. The X-OR-Split is used to trigger only one outgoing flow. It is best used for automatically choosing between a number of possible exclusive alternatives once a task completes.



AND-Split. The AND-Split is used to start a number of task instances simultaneously. It can be viewed as a specialization of the OR-Split, where work will be triggered to start on all outgoing flows.



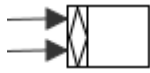
OR-Split. The OR-Split is used to trigger some, but not necessarily all outgoing flows to other tasks. It is best used when we won't know until run-time exactly what concurrent resultant work can lead from the completion of a task.



AND-Join. A task with an AND-Join will wait to receive completed work from all of its incoming flows before beginning. It is typically used to synchronize pre-requisite activities that must be completed before some new piece of work may begin.



XOR-Join. Once any work has completed on an incoming flow, a task with an XOR-Join will be capable of beginning work. It is typically used to allow new work to start so long as one of several different pieces of earlier work have been completed.



OR-Join. The OR-Join ensures that a task waits until all incoming flows have either finished, or will never finish. OR-Joins are “smart”: they will only wait for something if it is necessary to wait. However, understanding models with OR-joins can be tricky and therefore OR-joins should be used sparingly.

All of the above modelling elements support the control-flow perspective. On top of that, YAWL also provides full support for the Data perspective, which defines the specific characteristics of data and the way that they are used by tasks throughout the process lifecycle. YAWL also provides support for the resource perspective, in the means of defining constraints in the way that a work item may be executed, allocation of resources, triggering of events, etc.

YAWL provides also support for exception handling, which is a deviation from the normal path of execution when unexpected events occur. Exception handling is managed through the concept of **worklets**, which is an extensible repertoire of self-contained sub-processes and associated selection rules. Each worklet is a complete extended workflow-net (EWF-net). By allowing the designer of a process to designate certain work items to each be substituted at runtime with a dynamically selected worklet, YAWL provides flexibility for large and complex process activities.

Unified Modelling Language - UML

Each diagram has the same basic structure, as they are made up of ‘nodes’ that are joined together via ‘paths’. Obviously nodes and paths have different semantics in each type of diagram. In the following sections we will briefly present these types of diagrams.

8.1.1.1 The Class Diagram

Class diagrams represent the structural aspect of the system and have got many uses. They provide the means to describe the concepts of a domain and the relations between these concepts.

The basic elements of a class diagram are the *class* and the *relationship*.

A **class** represents a basic concept of the modelled domain and is depicted graphically by using a rectangle. A class can have one or more attributes and a set of operations that can be applied to the instances of the class. Classes are the basic nodes of a UML diagram.

A **relationship** represents the identification of a conceptual relationship between one or more classes. A relationship is graphically depicted by variations of a line, depending on the type of the relationship. There are four different types of relationships:

The association, which is the most basic of the four and is used to express simple conceptual relationships between two classes,

The aggregation, which is used to express relationships of the type “is made up of” between classes, allows the structure of a class to be broken down into a number of component classes.

The specialization, which allows a “has types” relationship to be defined, can be used to further classify classes into different “types of groups”.

The dependency which is used to express that two classes are tightly coupled in the form that whenever one of them changes then the other also needs to change.

Following are the symbols used for each one of these basic elements.

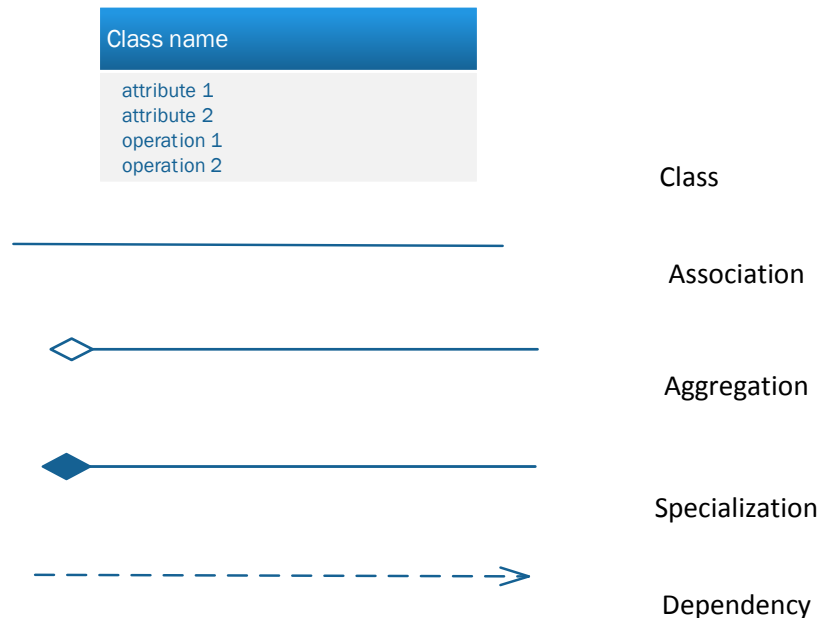


Figure 120 Basic Class Diagram notation

8.1.1.2 The Activity Diagram

The Activity Diagram realizes a behavioral aspect of the overall model, as it is used to model the low-level or detailed behavior of some class. Activity diagram derives from the flowchart, which is a diagram that most people are familiar with. They are heavily used in process modelling in order to realize the “process behavior view” of the process meta-model. This view is a set of activity diagrams, each of which describes the behavior of a single process.

The basic elements within the activity diagram are:

Activity invocation

Activity invocation: This is the execution of an operation, taken from its owner-class, which is the class whose behavior is being defined by the activity diagram.

Each activity invocation represents the processes of some sort of information and is also possible to represent activity invocations that receive or send messages from and to the outside world. These messages are also known as **signals**.

→ **Control and object flows:** These flows define the particular order that activity invocations must be executed by relating these invocations together in an ordered fashion. Flows are graphically represented by directed lines, the ends of which attach to activity invocations.

■ **Control forks and joins:** Sometimes the flow of control must be split in flows that will be concurrently executed. This is achieved with the use of a control fork that splits a single incoming flow to any number of concurrent flows that may or may not be executed in parallel. These split flows can be later joined back together using the control join.

:class name

Object nodes: Objects are used to represent information flow within the activity diagram, which is useful for showing the inputs and outputs of each activity information. They can be represented as instances on the diagram (a rectangle with the class name underlined and a preceding colon) or by simply showing text on a line.



Start and end states: Each activity diagram must have a start and an end. This represents the creation and destruction of an instance of the owner class.

Swim lanes: These are regions that are used for allocating responsibility to activity invocations. Each swim lane has the name of a stakeholder at the top, meaning that the respective stakeholder is responsible for the execution of the activities that are contained inside the swim lane.

8.1.1.3 *The Sequence Diagram*

The sequence diagram realizes a behavioral aspect of the overall model and is used to model high-level behavior. This type of diagram is used for tying different views of the system together and forms the basis of the process validation. These process instance views are used to represent Use Cases associated with particular requirements that are used for validation.

The graphical notation for a sequence diagram is shown in Figure 121

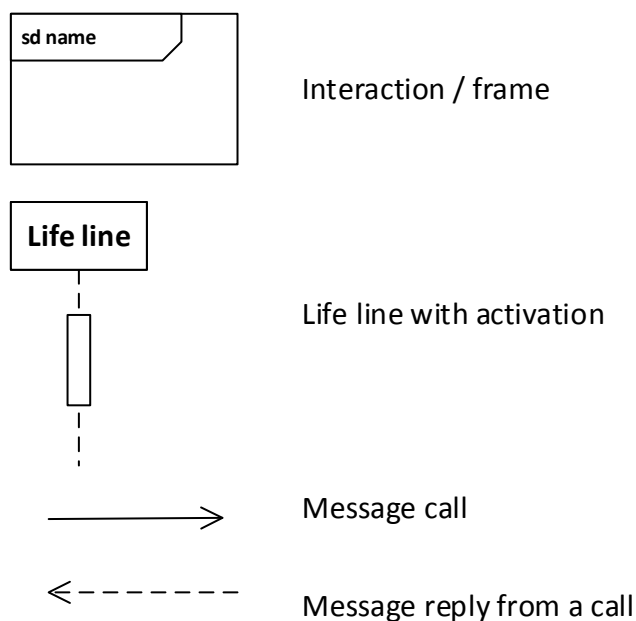


Figure 121 Basic notation of Sequence Diagram

An **interaction** is a representation of an ordered set of activities that are executed in order to fulfill a particular requirement. Each interaction is defined using a sequence diagram and each sequence diagram has a frame around it that identifies the particular interaction. Any one of these interactions can now be called up during any other interaction so that interactions may be nested.

A **life line** represents an instance, or collection of instances of a class. A life line is represented graphically by a box with the name of the parent class in it with a dotted vertical line underneath it. This line represents time, going down the page. A vertical oriented rectangle shows the creation and the destruction of an instance of the class.

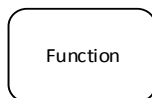
A **message** is the basic communication mechanism between life lines and can represent almost any form of information exchange, namely a true data exchange or a simple control message one.

Event-Driven Process Chains - EPC

The basic notation used in EPC diagrams is the following:



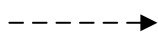
Event: An event is a passive element used to describe under which circumstances a process or a function works, or to which state a process or a function results in. Every EPC diagram starts and ends with an event.



Function: A function is an active element which is used to describe the tasks or activities of a business process. If a function corresponds to a high level business process then it can be refined to another EPC diagram.



Logical Connectors: These symbols (XOR, OR, AND respectively) are used to denote branch/merge or fork/join for either initiating multiple control flow paths from a single one or reverting to one execution path when multiple paths finish.



Control flows: A control flow is used to interconnect the three main concepts of EPC diagram (events, functions and logical connectors) in order to denote dependencies between them.

Every EPC diagram has got at least one start event and one end event. Events on the other side have at most one incoming and one outgoing arc, while functions have exactly one incoming and outgoing arc. Connectors have either one incoming arc and multiple outgoing arcs or the exact opposite. There can be no interconnection between two events or two functions.