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 D5.5

Final System Evaluation Report

Deliverable Status:	**Final**
File Name:	**SatisFactory-D5.5.pdf**
Due Date:	**December 2017 (M36)**
Submission Date:	**December 2017 (M36)**
Task 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:		
CERTH[1]	Centre for Research and Technology Hellas	Greece
SIGMA[2]	Sigma Orionis SA	France
FRAUNHOFER	Fraunhofer-Gesellschaft zur Foerderung der Angewandten Forschung E.V	Germany
COMAU	Comau S.p.A	Italy
EPFL	Ecole Polytechnique Fédérale de Lausanne	Switzerland
ISMB	Istituto Superiore Mario Boella sulle tecnologie dell'informazione e delle telecomunicazioni	Italy
ABE	Atlantis Engineering SA	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 PC	Greece

[1] Project Coordinator

[2] Terminated beneficiary since June 2016 and replaced by QPLAN

AUTHORS LIST

Leading Author (Editor)			
Surname	**First Name**	**Beneficiary**	**Contact email**
Parcharidis	Symeon	SUNLIGHT	s.parcharidis@sunlight.gr

Co-authors (in alphabetic order)				
#	**First Name**	**Surname**	**Beneficiary**	**Contact email**
1	Damiano	Arena	EPFL	damiano.arena@epfl.ch
2	Georgios	Barlas	SUNLIGHT	g.barlas@sunlighlt.gr
3	Luca	Bergamaschi	COMAU	luca.bergamaschi@comau.com
4	Vasiliki	Charisi	ABE	charisi@abe.gr
5	Pietro	Cultrona	COMAU	pietro.cultrona@comau.com
6	Fiore	Davide	REGOLA	d.fiore@regola.it
7	Emiliano	Della Casa	GlassUP	emiliano.dellacasa@glassup.net
8	Georgios	Efremidis	ABE	de@abe.gr
9	Erion	Elmasllari	FIT	erion.elmasllari@fit.fraunhofer.de
10	Dimosthenis	Ioannidis	CERTH	djoannid@iti.gr
11	Massimo	Ippolito	COMAU	massimo.ippolito@comau.com
12	Stefanos	Kanidis	SUNLIGHT	s.kanidis@sunlight.gr
13	Stelios	Krinidis	CERTH	krinidis@iti.gr
14	Evdoxia Irini	Lithoxoidou	CERTH	elithoxo@iti.gr
15	Ifigeneia	Metaxa	ABE	metaxa@abe.gr
16	Konstantinos	Paspalas	SUNLIGHT	k.paspalas@sunlight.gr
17	Michele	Putero	COMAU	michele.putero@comau.com
18	Ployvios	Raxis	ABE	rtd@sbe.gr
19	Sarah Leon	Rojas	FIT	sarah.leon.rojas@fit.fraunhofer.de
20	Antonio	Serra	REGOLA	a.serra@regola.it
21	Dimitra	Triantafyllou	CERTH	dtriant@iti.gr

22	Athanasios	Tsakiris	CERTH	atsakir@iti.gr
23	Apostolos	Tsolakis	CERTH	tsolakis@iti.gr
24	Cosmas	Vamvalis	ABE	vamvalis@abe.gr
25	Paolo	Vergori	ISMB	vergori@ismb.it
26	Stelios	Zikos	CERTH	szikos@iti.gr

REVIEWERS LIST

List of Reviewers (in alphabetic order)				
#	First Name	Surname	Beneficiary	Contact email
1	Emiliano	Della Casa	GlassUP	emiliano.dellacasa@glassup.net
2	Anastasia	Matonaki	QPLAN	matonaki@qplan.gr

REVISION CONTROL

Version	Author	Date	Status
0.1	SUNLIGHT	October 5, 2017	Initial Draft, ToC
0.2	EPFL, ABE, SUNLIGHT	November 17, 2017	ToC revision, Charts from 1st Data Collection, Evaluation Methodology and Plans, SUNLIGHT BSCs
0.3	EPFL, ABE, GLASSUP, ISMB	December 2, 2017	Contributions to Lessons Learned chapter, Charts from 2nd Data Collection
0.4	EPFL, ABE, GLASSUP, ISMB CERTH, REGOLA, SUNLIGHT, COMAU, FIT	December 15, 2017	COMAU BSCs, Contributions to Lessons Learned chapter, Revision of charts, Overall results assessment from SUNLIGHT
0.5	CERTH, SUNLIGHT, COMAU, FIT	December 20, 2017	Contributions to Lessons Learned chapter, Results description, Overall results assessment from COMAU
0.6	SUNLIGHT	December 22, 2017	Overview and submission for review
0.7	QPLAN, GLASSUP	December 27, 2017	Quality Check Final Draft reviewed
1.0	**SUNLIGHT**	**December 31, 2017**	**Ready for submission to the EC**

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

List of Definitions & Abbreviations

Abbreviation	Definition
EC	European Commission
EU	European Union
AI	Artificial Intelligence
AR	Augmented Reality
AURA	COMAU Advanced Use Robotic Arm
BSC	Business Scenario
DSS	Decision Support System
ES	Evaluation Scenario
ET	Evaluation Test
IIoT	Industrial Internet of Things
IoT	Intenet of Things
ORS	Object Recognition System
PaaS	Platform as a Service
PoC	Proof of Concept
QoS	Quality of Service
SaaS	Software as a Service
SLA	Service Level Agreement
SUS	System Usability Scale
VR	Virtual Reality
WCM	World Class Manufacturing
WTH	Willingness to Have

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).

The main objective of this deliverable is to report on the SatisFactory Final System Evaluation, with regards to the industrial pilots at COMAU and SUNLIGHT. The evaluation of SatisFactory platform is based on the implementation of the business scenarios where each toolkit meant to be used. The scenarios have been updated after their initial version, as developed in T1.3 Use case and Scenarios. Each component was tested separately from its initial installation, even if the scenarios were not able to be completely implemented due to missing components. The way in which each business scenario was finally implemented has been presented in the deliverable D5.4 ("Industrial Pilots Set-up and Demonstration") in M26 and in its second iteration in M35.

The evaluation of the SatisFactory platform was conducted according to the methodology and evaluation plan developed in the task T5.2 'Evaluation Methodology and Plans'. The methodology has been tested and validated at the industrial lab environment of CERTH/CPERI. The methodology and plans have been also presented in the first and second version of D5.2. The evaluation scenarios and tests have been revised and updated where necessary, to keep in line with the developments of the SatisFactory components. In the evaluation of the industrial pilots of COMAU and SUNLIGHT, which is presented in this deliverable, the final version of the evaluation methodology and plans has been used.

Finally, the partners who developed the components of SatisFactory platform, mention in this report their lessons learned through their involvement in the SatisFactory project. The D5.5 is completed by presenting the overall conclusions of SatisFactory's pilots of CERTH/CREPI, COMAU and SUNLIGHT.

1. INTRODUCTION

The scope of the Final System Evaluation Report is to evaluate the SatisFactory platform as it was implemented and used at the industrial pilot sites of COMAU and SUNLIGHT, as well as to present the lessons learned through the development of the components and to report the overall conclusions of SatisFactory's pilots at CERTH/CREPI, COMAU and SUNLIGHT.

Chapter 2 presents the business scenarios at their final state, as reported in the deliverable D5.4 "Industrial Pilots Set-up and Demonstration". The two business scenarios (BSCs) of COMAU (BSC1.1 and BSC1.2) and the four BSCs of SUNLIGHT (BSC3.1, BSC4.1, BSC4.2 and BSC4.3) are briefly described.

Chapter 3 describes the evaluation methodology based on which COMAU and SUNLIGHT evaluated the SatisFactory project. The evaluation methodology is described in detail in deliverable D5.2 "Evaluation Methodology and Plans".

Chapter 4 presents in detail the results of the evaluation conducted in COMAU and SUNLIGHT. The chapter is separated into three parts. In the first and second part, the results of COMAU's and SUNLIGHT's evaluation and their overall conclusions are reported respectively, while in the third part, the total report of the results of the end users' evaluation at CERTH/CPERI, COMAU and SUNLIGHT is provided.

Eventually, in chapter 5, the partners who developed the components describe the lessons learned from their involvement in the SatisFactory project.

2. INDUSTRIAL PILOTS SET-UP AND DEMONSTRATION

The aim of this chapter is to briefly present the BSCs of COMAU and SUNLIGHT. The initial architecture of the BSCs is presented in deliverable D1.2 and details about the implementation of the BSCs on the Shop-Floor of COMAU and SUNLIGHT are provided in deliverable D5.4.

2.1 COMAU BSCs

This chapter summarizes the description of the BSCs addressed in COMAU's premises by SatisFactory project. A complete and satisfactory description of these BSCs, could be found by eager reader inside the different iterations of deliverable D1.1 "User Groups Definition, End User Needs, Requirements Analysis and Development Guidelines", and of deliverable D5.4 "Industrial Pilots Set-Up and Demonstration".

Here, as well as into the last iteration of D5.4 (D5.4.2), a brief subchapter has been added, describing a new Business Scenario that has recently been introduced into COMAU's ShopFloor. Thanks to well-structured and effective internal dissemination activities, led by COMAU together with all other partners, internal stakeholders (Manufacturing management), asked SatisFactory team to implement their tools on a new development area, devoted to an iconic product, perfectly fitting Industry 4.0, digital transformation and SatisFactory project's aims and drivers: COMAU AURA (Advanced Use Robotic Arm) collaborative robot (see Figure 1).

Figure 1 COMAU AURA Robot

2.1.1 BSC 1.1 – Robot Wrist Assembly

Industrial robots like COMAU ones, are made up by one mechanical structure (mechanical chain, sensors and actuators) and a control unit governing robot movements (see Figure 2 below and Figure 3 later on for mechanical structure).

Figure 2 COMAU 5th generation robots controller, C5G

Figure 3 COMAU NJ 110 / 130 in new, grey outfit

Industrial robot mechanical chain is made up by links, i.e. stiff physical components connected to each other by joint, granting instead robot degrees of freedom.

COMAU robots family encompasses various categories of robots (among which SCARA Manipulators); Nevertheless, COMAU NJ 110 / 130, which was taken into account for SatisFactory project, is an anthropomorphic articulated robot.

Industrial anthropomorphic articulated robot is usually made up by six links and relevant six joints, allowing for movement accordingly to six axes. Some robots can then be equipped with additional axes, usually installed prior to first link – robot "Base" – like turning tables and linear slides, or on the tool – robot "End Effector" – connected to last link, i.e. robot "Flange".

Anyway, last three robot links, into six-axes configuration, constitute the so-called robot "Wrist", ensuring orientation degrees of freedom to the end effector.

NJ 110 / 130 robot wrist taken under consideration into BSC 1.1 is indeed comprehensive of part of fourth robot link (gearbox), fifth swinging link and the flange, plus fifth and sixth joints / axes.

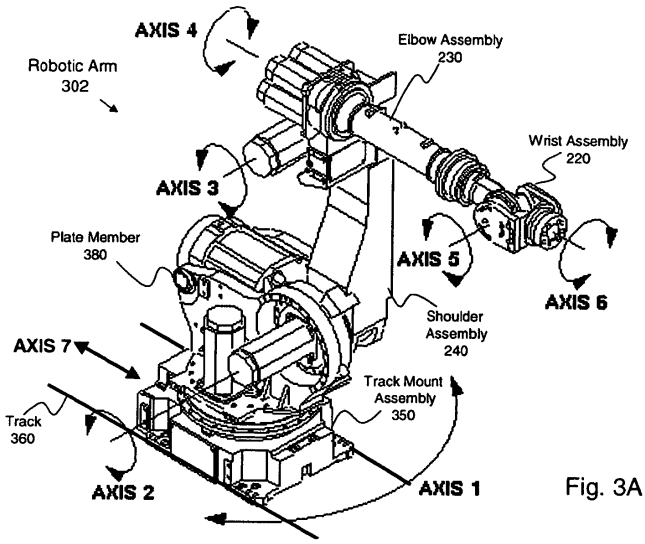


Figure 4 Industrial, anthropomorphic robot mechanical chain schema

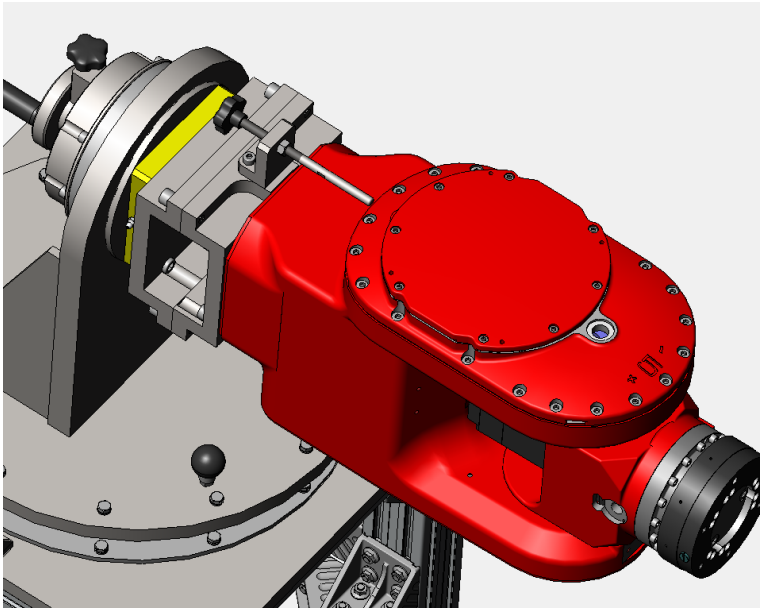


Figure 5 COMAU NJ 110 / 130 complete robot wrist on online assembly support / tool

Traditional wrist assembly WorkPlace consists of a mainly manual work station where COMAU operators perform specific operations sequences, which must be strictly followed in order to ensure performance and the high reliability level characterizing COMAU products.

Complete manufacturing process includes operations that can fairly be clustered into:

- Components preparation, i.e. cleaning or physical / chemical treatments.
- Assembly of Bill of Materials (BOM) components. Consider that COMAU NJ 110 / 130 robot wrists easily contains more than 60 different part numbers!

Assembly activities can comprehend adhesive bonding / sealing, insertion / planting and screwing.

- Application of piping and wiring or grease and oil filling.
- Traceability activities.
- Static testing of tolerances and mechanical couplings.

Operations onto wrist assembly WorkPlace are performed mainly manually by Process Operators, using manual or at least semi-automatic assembly and testing tools. Process Operators are specialized workers with mechatronics skill, i.e. competences in mechanical assembly, wiring and piping, testing, plus troubleshooting (problem solving).

Figure 6 Process Operators during piping installation on a robot arm

One important aspect of the manual operations conducted in robot wrists assembly is that both hands are required to perform the operations, thus different presentation tools from tables are required, such as fixed terminals, docking stations or glasses.

It has been decided to reserve an area into COMAU ShowRoom for an ad-hoc fitted booth, representing the master for a new concept of WorkPlace that would be introduced into COMAU NJ 110 / 130 wrist assembly real workflow and deserves to be spread across the factory and to other potentially interested companies, that can experience it into COMAU ShowRoom.

On such WorkPlace an abstract of complete wrist assembly procedure has been implemented, taking into account just more relevant activities that can be easily shown in public and can catch and draw people attention.

2.1.2 BSC 1.2 Remote Maintenance Support

Instead of focusing again on the same step of product value-chain, i.e. the “babyness” of automation, Remote Maintenance Support BSC, moves forward throughout COMAU product life-cycle, and applies SatisFactory principles over maintenance activities, performed on COMAU automation products that, thanks to their standard nature, will earn the highest benefit from procedure execution, multimedia enriched supports.

This Business Scenario involves Customer Care Department, i.e. COMAU After Sales, always consisting of highly-skilled problem-solving technicians with a high-profile, that are very difficult to find on the market, especially in consideration of the high turnover of contemporary workforce.

Let's think that required competences for COMAU Service Engineers used to range from analytical and methodological approaches toward troubleshooting and problem solving, to practical on field intervention, both on just measuring plus inspection purposes and consisting of manual repair / parts replacement on the machine. They are both asked to grant Their availability to emergency support calls and to rashly intervene physically on customer premise, potentially out of office hours or during holidays / weekends. This situation classifies this job as a challenging one.

The tasks They are asked to perform are mainly related to:

- Programmed pre-emptive (periodic) professional maintenance activities, accordingly to maintenance calendars;
- Support System Engineers into maintenance procedures creation and preventive maintenance schedules definition (thanks to capitalized lessons learned);
- Maintaining and enhancing, improving COMAU products value during their whole useful life
- Emergency intervention in case of machine fault or breakdown that cannot be immediately restored by customer technicians on their own.

Furthermore, Service Engineers are asked to face "background asymmetry", i.e. difficulty of communicating with people whose technical skills are not as strong as COMAU Service Engineers' are or that misinterpret instructions. These are the main reasons why local presence of COMAU technicians is lot of times required.

Having experienced resources traveling frequently or lending them to customer on premise, results in costs, that should be avoided if a more effective remote support than rush night calls is made available. The objective of BSC 1.2 is having a remote support consisting into Voice over IP (VoIP) and video real-time streaming in mobility, plus the possibility of having COMAU Service Engineers drawing instructions based on video streams coming from the field, that will be shown, in AR, on client side, e.g. on AR glasses.

This solution would support both COMAU young Service Engineers on-the-job training, customer maintenance technicians "tele-guidance" from COMAU premises and in the worst case, assistance to COMAU resources eventually sent to customer plants but that, in this case, could be less skilled resources.

Remote support would be needed if and only if standard maintenance procedures would not be enough for technicians to solve issues on their own.

A typical user story for this scenario should be:

1) Customer maintenance technician is asked to start and intervention procedure (whether a breakdown / fault or a periodic activity);
2) The technician can use multi-platform (tablets and smartphones, wearables like smartglasses, …) support to access to multimedia enriched procedures (image targets based or markerless AR, immersive VR, videos, pictures, documentation, …);
3) In case the task execution would not be effective, the technician can ask for expert technical support starting a call, during which pictures and video streams could be shared bi-directionally in real time, documentation can be send remotely and, more

important, Service Engineer can add information (text or hand-drawn instructions) that will be displayed in AR;

4) In case anyway also this intervention fails, a COMAU junior Service Engineer would be sent on site and the process would restart from point 1 or 2 (with just a change in actors).

2.1.3 COMAU AURA Robot Assembly

As stated at the beginning of this chapter, a new stunning exploitation opportunity for SatisFactory platform recently came out in COMAU ShopFloor, thanks to the impact of internal dissemination activities on the top management: application of SatisFactory suite on COMAU AURA (Advanced Use Robotic Arm) collaborative robot assembly area.

The involved cell is a highly digitalized WorkPlace, where electronics installations and mechanical assembly of AURA robots collaborative covers are performed, mainly manually.

Three main exploitation macro phases have been defined for implementation, while each phase would be managed incrementally with Agile methodologies (i.e. Scrum Cycles). The steps have been summarized in below architectural schema (Figure 7), briefly explained later on.

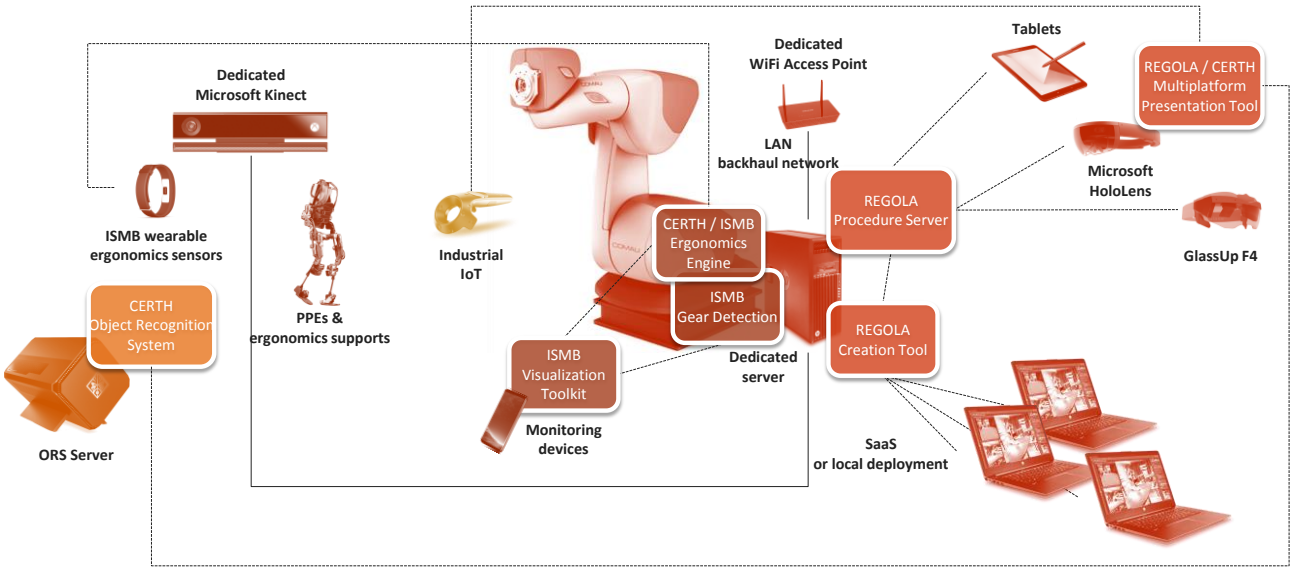


Figure 7 COMAU AURA Robot assembly area implementation

The first implementation step, highlighted with a shrimp-red color (■) would, potentially, foresee the deployment on a dedicated COMAU server, installed into the ShopFloor, of:

- Creation Tool, developed by REGOLA with plugins for markerless Object Recognition System (ORS), developed by CERTH / ITI.

Creation Tool is one of the first development environments (SDKs) for industrial procedures ad AR contents generation. Installing it on the ShopFloor can sound weird; Line Operators would indeed not use it directly. But it is a first step forward in making a SaaS (Software as a Service) of REGOLA tool that System Engineers / Manufacturing Leaders (dealing in COMAU with assembly procedures creation) can access concurrently with thin clients, without the need of encumbering their own PCs with additional software. Obviously further efforts would be needed to convert the overall infrastructure and to ensure an acceptable SLA (Service Level Agreement).

By so, a back-up solution, to manage the transition, would be having anyway also a local installation of the tool on System Engineers / Manufacturing Leaders PCs plus accessing via remote desktop (or similar protocols) to the shared server.

- Procedure Server, again developed by REGOLA.

This service allows for procedures exportation from Creation Tool and sharing on a dedicated WiFi network, set up for the project on the ShopFloor.

A potential future improvement / strengthening of this solution would be the possibility of having a sharing platform on-Cloud, with a Private Cloud solution, to ensure data security, or even with a local deployment of the Cloud platform.

The procedure server would then expose assembly procedures for the subscribing devices that would connect from the ShopFloor. These devices will encompass tablets (and smartphones), fixed displays plus wearable devices, especially smartglasses (GLASSUP F4, especially effective for information visualization and remote support features, and HoloLens, more suitable for AR applications).

The devices, given to Line Operators, should have Presentation Tool installed, one solution developed by REGOLA with CERTH contribution (on markerless object recognition purpose) for SatisFactory project. Presentation Tool should furthermore be integrated with hands free browsing (e.g. gesture recognition or HoloLens internal navigation system), in order to allow Line Operators availing themselves of augmented assembly procedures without having hand encumbered by hardware, bur living them free to perform value added activities on the workpiece.

Above description will complete the scope of implementation step 1. Exploitation phase 2 – highlighted with a mustard-yellow color (■) in the architectural schema (Figure 7) would instead deal with the integration of IIot, i.e. Industrial Internet of Things (IoT) inside the already deployed platform.

This means using inputs from industrial equipment (mainly traceability devices for manual operations, like barcode readers, portable or even wearable) as a trigger inside assembly procedures, inserting conditional nodes or even sending commands to pieces of automation in the area.

Then step 3 would come – please see elements highlighted in dark magenta (■) inside Figure 7. Phase 3 would focus on adaptability of WorkPlace to workers; first of all, the cooperation of wearable sensors designed and programmed by ISMB, real time ShopFloor monitoring again developed by ISMB and finally ergonomics data / alerts analysis engine

made in CERTH / ITI, would create the soil for decision aid systems suggesting adaptively right supports (PPEs or other) for different Line Operators.

The use of a Microsoft Kinect camera and of markerless / image target based recognition systems (developed by ISMB), would then check if people are wearing the right PPEs and following the prescriptions; in case these conditions are not fully satisfied, relevant warning would be show on ISMB ShopFloor monitoring platform, collecting all information needed by resources supervisors (Manufacturing Leaders in COMAU).

Last but not least, the fourth step – orange (■) supercomputer on the leftmost side of Figure 7 – would integrate CERTH / ITI Object Recognition System with already deployed Creation and Presentation Tools. This would benefit in avoiding ShopFloor "wallpapering" with stickers (2D image targets) requiring a strict positioning precision (since they would serve as reference systems for 3D models projection in AR) and would even allow for more flexibility in process / WorkPlace reconfiguration.

Further steps should anyway be undertaken to improve ORS performances (i.e. responsiveness, nevertheless the computational resources required for AI – Artificial Intelligence – algorithms execution is not negligible) and flexibility, i.e. the possibility of training the system to new object recognition independently by the developers of the tool.

The choice of AURA robot area would finally be especially important for SatisFactory project and – later on – for SatisFactory products suite, since – as highly digitalized WorkPlace – it would be a showcase in COMAU, giving a fundamental boost to dissemination both internally (inside COMAU) and externally.

2.2 SUNLIGHT BSCs

In this subchapter will be presented the BSCs of Sunlight where the components of SatisFactory platform were used. More details, regarding the BSCs may found in deliverables D1.2 "Use Case Analysis and Application Scenarios Description" and D5.4 "Industrial Pilots Set-Up and Demonstration".

Table 1 List of SUNLIGHT BSCs

Business Scenario	Application Scenario	Name
BSC-3	*Knowledge-enabled support of systems and workforce for semi-automated battery assembly lines*	
	BSC 3.1	Preventive and corrective maintenance management system
BSC-4	*Monitoring and learning activities at battery production lines*	
	BSC 4.1	Motive power battery assembly line
	BSC 4.2	Monitoring of cell temperature during jar formation and data collection
	BSC 4.3	Training platform for production process motive power batteries

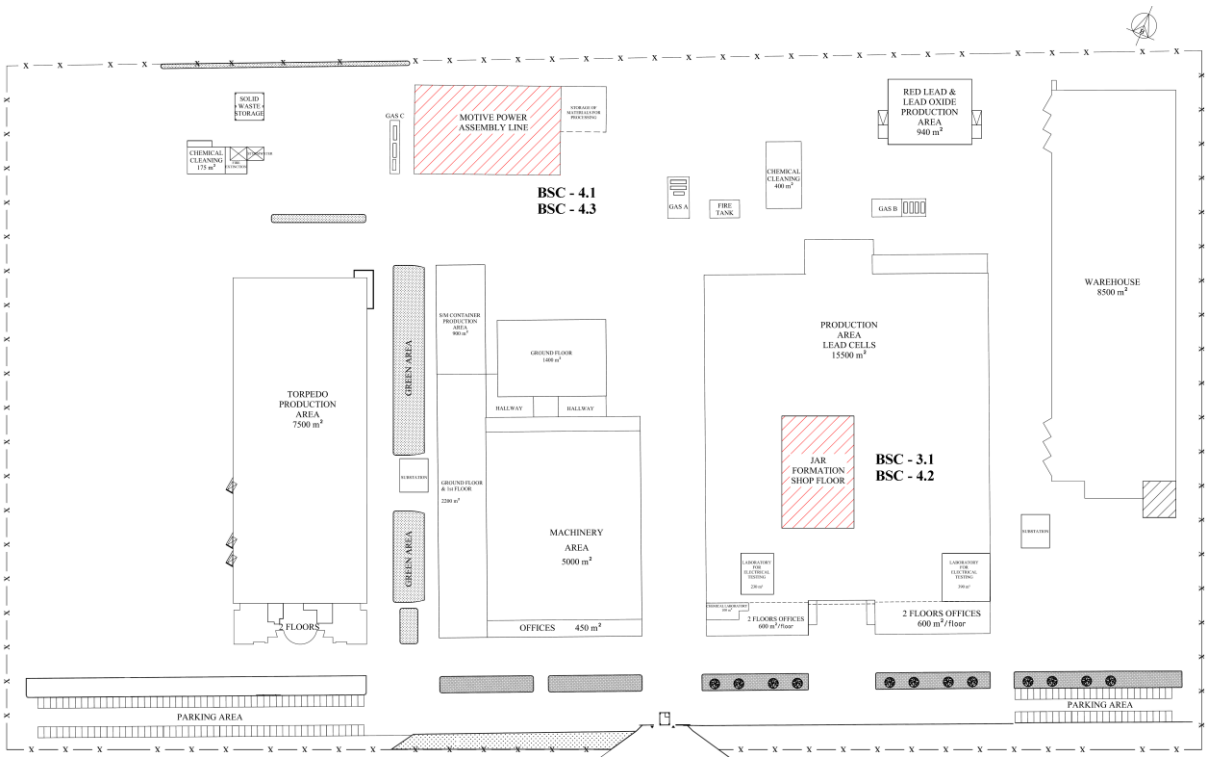


Figure 8 SUNLIGHT factory overview, Business Scenarios related ShopFloors location

2.2.1 BSC 3.1 – Preventive and Corrective Maintenance Management System

The BSC 3.1 has as main goal to support the actions and procedures of maintenance department. The components of SatisFactory may assist the actors to almost every step of a maintenance task, from its declaration to execution and even fulfilling the final report. In BSC 3.1 are involved 12 people in total, 3 foremen and 3 workers from the production line and 1 maintenance manager, 1 maintenance supervisor, 2 electrical technicians and 2 mechanical technicians from maintenance department.

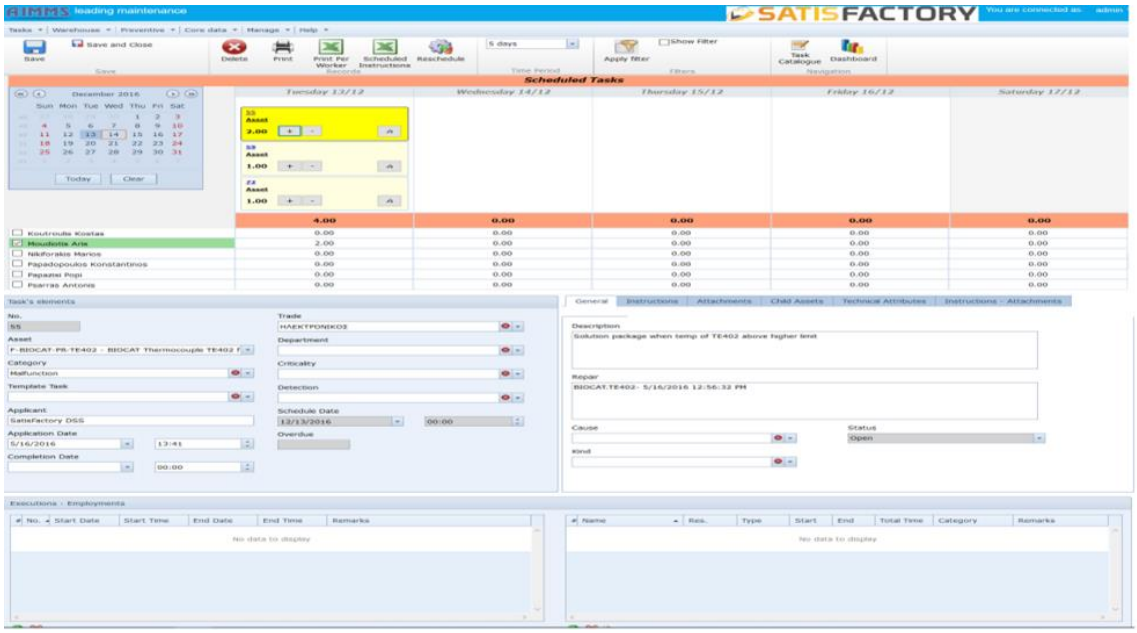


Figure 9 Initial scheduling into Maintenance Toolkit Calendar View

The application scenario of BSC 3.1 may summarized in the following bulleted list:

- **Failure event notification by:**
  - Foremen or Technicians or Workers
  - iDSS
- **Action planning by:**
  - Maintenance Supervisor
    advised by:
    - iDSS
    - Ontology
    - Localization manager
- **Work scheduling by:**
  - Maintenance Manager
    advised by:
    - iDSS
    - Ontology
- **Tasks assignment by:**
  - Maintenance Manager advised by:
    - iDSS
    - Ontology
- **Work execution by:**
  - Technicians (Electrical, Mechanical)
    supported by:
    - AR glasses
    - Tablets
    - Smartphones
- **Work completion by:**

- Technicians (Electrical, Mechanical) report to:
  - AIMMS
- Maintenance Supervisor report to:
  - AIMMS

- **Production of intervention reports**
  - Maintenance Supervisor report to:
    - AIMMS
  - Maintenance Manager is informed

2.2.2 BSC 4.1 – Motive Power Battery Assembly Line

Creating batteries is not always fascinating and the lack of excitement, reduces the performance of workers. BSC 4.1 focuses on workers satisfaction but not only. Satisfaction is one goal of this BSC, the other one and maybe the most important is safety. This scenario is implemented on Motive Power Battery Assembly Line shop floor, Gesture recognition, AR technologies, Localization manager and many more components are looking cool even to the younger workers and also are able to augment safety measures. In this scenario are involved 16 people in total, 1 production manager, 2 production supervisor, 3 foremen and 10 workers, all from the Motive Power Battery Production Line.

Figure 10 Smart Assembly Station operating screenshots from the old production line

The main components which are used in each process in Motive Power Battery Assembly Line are:

- **Packing cells into metallic boxes**

- Gesture & Content Recognition Manager
- Digital Andon Station

- **Connect cells altogether creating a battery string**
  - AR OP Presentation Tools
  - Localization Manager
- **Installing terminal plugs and water filling system**
  - AR OP Presentation Tools
  - Localization Manager
- **Checking the need for additional electrolyte**
  - AR OP Presentation Tools
  - Localization Manager
- **Passing from quality check**
  - Localization Manager
- **Putting labels, packing and forwarding to warehouse for dispatch**
  - Localization Manager

2.2.3 BSC 4.2 – Monitoring of Cell Temperature during Jar Formation and Data Collection

This scenario is similar to BSC 3.1, it differentiates on use of advanced technological means to monitor and notify of malfunction. This scenario is implemented in Jar Formation shop floor and 14 people were involved in total, 2 production supervisors, 3 foremen and 3 workers from production line and 1 maintenance manager, 1 maintenance supervisor, 2 electrical technicians and 2 mechanical technicians from maintenance department.

Figure 11 Thermal cameras

The application scenario of BSC 4.2 may summarized in the following bulleted list:

- **Identification of condition-based preventive action by:**
  - Thermal camera
- **Alarm recognition by:**
  - Foreman or Worker
    - Wall screen
    - Tablet
    - Smartphone
- **Alarm acknowledgment by:**
  - Production and Maintenance Supervisor
    - Tablet
    - Smartphone
- **Tasks assignment by:**
  - Maintenance Manager advised by:
    - iDSS
    - Ontology
    - Localization manager
- **Work execution by:**
  - Technicians (Electrical, Mechanical) supported by:
    - AR glasses
    - Tablets
    - Smartphones
  - Technicians (Electrical, Mechanical) report on:
    - AIMMS
    - Maintenance Supervisor report on:
    - AIMMS
    - Ontology
- **Production of intervention reports by:**
  - Maintenance Supervisor report on:
    - AIMMS
    - Maintenance Manager

2.2.4 BSC 4.3 – Training Platform for Production Process on Motive Power Batteries Assembly Line

The last scenario that is implemented in Sunlight is BSC 4.3. This scenario is focusing on training of personnel on the production processes on Motive Power Batteries Assembly Line. The platform is able to provide theoretical information, multimedia and AR tools to make the training process more attractive, plus to provide to the workers all the information needed. The training platform include, also, a gamification part, the purpose is to gamify the training process, give points to the trainees as they process to their training, write comments, make or vote suggestion and many more.

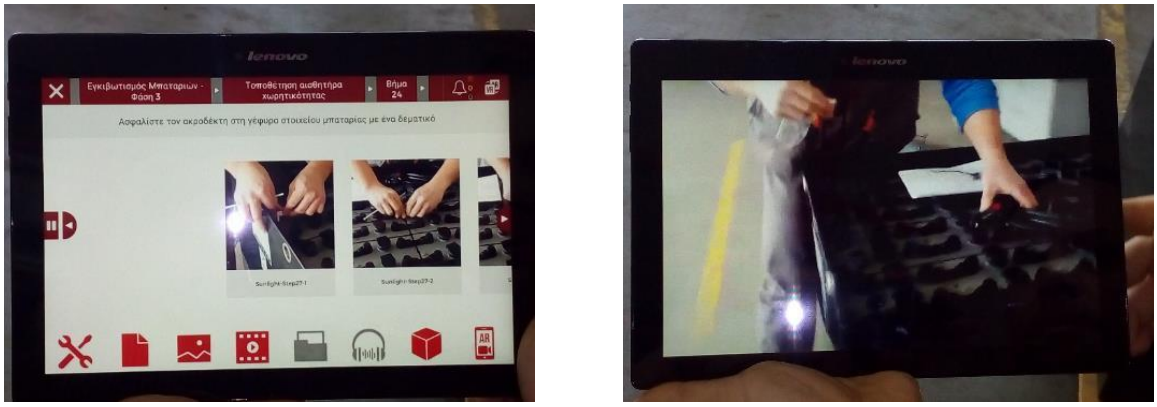


Figure 12 AR in-Factory platform – Visualization Tool

- **Identification of training needs by:**
  - Production Supervisor advised by:
    - Collaboration Platform
    - Gamification Platform
- **Training on the workplace for:**
  - Workers supported by:
    - AR in-Factory Platform
- **Training feedback by:**
  - Workers or Foremen through:
    - Collaboration Platform
    - Gamification Platform
- **Provision of training material by:**
  - Production Supervisor
  - Production Manager

3. EVALUATION METHODOLOGY AND PLANS

As it has been described in D5.2 “Evaluation Methodology and Plans”, **the objective of the SatisFactory evaluation framework** is to provide the methodology to evaluate the fulfilment of the project objectives with respect to the user (workers and decision makers) requirements. In order to do that, a series of evaluation scenarios and tests have been developed. The user-centred design approach has been applied also in the evaluation process, using evaluation iterations.

It is reminded that the framework for the evaluation of factory workers and decision makers’ appreciation has been based on the ***project objectives***:

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

The solution has been deployed and evaluated in an Industrial Lab pilot and in large-scale Industrial Facilities from the Automotive and Energy factory domain (6th project objective). In order to present a more straightforward evaluation concept, it was necessary to translate the project objectives into end-user expectations and requirements; the ***evaluation objectives*** (their definition can be found in D5.2):

1. Performance improvement
2. Real-time knowledge-sharing
3. AR assisted operation and training
4. Collaborative working environment
5. Ease of use and overall satisfaction

From the end-user perspective, the fulfilment of these objectives was evaluated via the various BSCs defined in D1.2 “Use Case analysis and application scenarios description”, which in turn has capitalised from D1.1 “User group definitions, end-user needs, requirement analysis and deployment guidelines”. Also, D2.1 “SatisFactory system architecture” was used as the basis for the components to be evaluated in each BSC.

3.1 SATISFACTORY EVALUATION FRAMEWORK

It should be noted that in the core of the SatisFactory project lies the user-centric approach. The evaluation methodology framework should and has been based on this core value. After all, the worker involvement and satisfaction need to be carefully evaluated and improved, because the adoption of new technologies and tools is often delayed or even hindered by the

workers refusal to integrate them to their daily activities. Two main methodologies have been combined; the human-centred approach and the ECOGRAI method.

3.1.1 Human-centric Evaluation Methodology

The evaluation within SatisFactory follows the human-centred design approach according to the ISO 9241-210 Standard 210 (ISO 2010) as introduced in deliverable D1.1 “User group definitions, end-user needs, requirement analysis and deployment guidelines” and described in D5.2 “Evaluation Methodology and Plans”.

The main characteristic is the iterative approach in order to gain knowledge, derive requirements, produce design solutions and evaluate if they meet the requirements. For the collection of feedback, the concept of the focus groups was used; i.e. groups of end users or other experts that discuss designs given by somebody else and can revise them during the focus group sessions. The actual product is tested by potential end users on the field by performing typical test tasks with the product undergoing the test. The experts test whether the product does what it should do. Thinking out loud in a brainstorming environment is encouraged, in an attempt to better understand the point of view of the end users. During the first iterations, the focus was on whether the developed solutions are effective and efficient for completing the envisaged tasks, which led to optimisations.

It should be noted that the heuristic evaluation has been employed. It is an easy and effective method to detect the majority of issues, developed by (Nielsen 1994). The heuristic evaluation is conducted in 4 phases. In the preparation phase, the experts familiarize themselves with the product. Then, the actual evaluation is conducted according to the heuristics by 3-5 experts, optimally 2 runs, and 1-2 hours each. Each identified issue is assessed and documented according to its severity on a 5-point scale, taking into account its frequency, impact and persistency. In the results phase, the experts sit together in order to group problems according to the ratings. In the final solution finding phase, the experts brainstorm together with the developers.

Moreover, the System Usability Scale (Brooke 1996) approach was used, for computing subjective usability assessment of participants to a single number, using its lightweight schema with only 10 questions that need to be answered by the participants.

In the end, the evaluation of final implementations is checking for overall usability and user experience and whether the general ergonomic principles according to ISO 9241-110 are met (ISO 2006).

3.1.2 ECOGRAI Evaluation Methodology

The evaluation within SatisFactory also follows the ECOGRAI method, which was originally introduced to design and to implement Performance Indicator Systems (PIS) for industrial organizations and used by the decision makers of the Production Management Systems (PMS) to measure the achievement of their objectives (Doumeingts *et al.*, 1995).

The approach involves two stages: a) Top-down approach for the logical process of analysis, decomposing the objectives of the strategic levels into objectives for operational levels. b) Bottom-up approach for the concrete process of participative implementation.

The ECOGRAI methodology has been applied for the scope of the SatisFactory project for the selection of the KPIs to be investigated in order to evaluate the fulfilment of the project objectives and the value of its results at the workers' and at the decision makers' levels. A detailed analysis has been based on this methodology, taking also advantage of the existing evaluation framework and KPIs already existing in the shop floors. Certain phases are split into sub-phases for ease of the implementation (Lobna *et al.*, 2013).

The six basic steps of the ECOGRAI methodology are:

Phase 0: Modelling of the Production System Control Structure and Identification of the PCC

Phase 1: Identification of the PCC Objectives and Coherence Analysis

Phase 2: Identification of the PCC Drivers and analysis of the conflicts

Phase 3: Identification of the PCC PIs and Internal Coherence Analysis

Phase 4: Design of the PI Information System

Phase 5: Integration of the Performance Indicator information system in the Production information system

3.1.3 Combined Evaluation Methodology

The two methodologies previously described are complimentary, as they address the evaluation issue with a combined approach, considering the human factor, as well as the system for the availability and sharing of information and influences within an industrial environment. The combined evaluation methodology allows for the usage of tools from both approaches that are suitable for the scope of the SatisFactory project. The methodology is translated into the evaluation criteria described D5.2 "Evaluation Methodology and Plans". Moreover, a set of Criteria and Evaluation Tests have been used in the evaluation of the SatisFactory tools in all shop floors that they have been deployed.

3.2 EVALUATION PROCESS

The detailed evaluation process is analysed in D5.2. It is important to present an overview here, as the process itself should be kept in mind when going through the attained results. The goal is to evaluate in essence the exploitable outcomes from the end user's point of view. The user experience in relation with the business scenarios that people are involved is considered. It is reminded that there is a straightforward connection of the Business Scenarios (BSCs), Evaluation Scenarios (ESs), Evaluation Tests (ETs) and SatisFactory products.

3.2.1 Evaluation Scenarios

The Evaluation Scenarios briefly presented below are also tied to the evaluation objectives and criteria.

Evaluation Scenario ES1: Supporting Assembly Operations

The assembly operations are of critical importance, as they can be individual tasks or a set of steps in a broader task that workers need to undertake. They are common in automotive and heavy equipment industries, electronics, defence, aerospace, telecommunications, power & automation, energy & resource, naval engineering, as it has also been defined by AREA. There are two sub-scenarios, namely

ES1.1 Automated support for assembly operations: The worker is prompt to perform assembly operations in a standardised way. The support system automatically suggests the adaptation of the specific steps to be performed, feeds the information to the HR workbalance toolkit and provides the worker with the required information and visualisation tools to complete the task.

ES1.2 AR supported assembly operations: The worker is required to perform an assembly operation using an AR SOP Presentation Tool. The main goal is to address user satisfaction related to the performance of the provided tools (localisation, AR, recommendations given, assignments made etc.).

Evaluation Scenario ES2: Offering Maintenance, Re-adaptation & HR Workload Balancing Services

The scope is to evaluate the services offered related to maintenance (corrective and preventive), re-adaptation and HR workload balancing through the SatisFactory framework. These services are required for the efficient operation at the shop floor, to ensure that the equipment is up and running in order to fulfil production needs, to ensure the safety of the workers at the shop floor level, to reduce the work-related stress and to efficiently manage human resources.

ES2.1 Corrective Maintenance, Re-adaptation & HR Workload Balancing: In this evaluation scenario, a failure in equipment occurs and the incident is detected, the work allocation is suggested as well as the re-adaptation of the scheduling. Moreover, the worker prompted to respond to take action is provided with the set of tools and information required to perform the task and he/she is able to collaborate with others who have taken care of similar work orders and to take advantage of their experiences.

ES2.2 Preventive Maintenance, Re-adaptation & HR Workload Balancing: This scenario is triggered when a scheduled preventive maintenance program is in turn to be realised. The prioritisation of activities is important, as well as the work scheduling, allowing for the complete preventive maintenance action to take place. The work allocation is suggested based on available resources taking into consideration that re-adaptation may be needed. The worker assigned to perform the task is provided with the tools and information required and is also informed on the SOP to be followed.

Evaluation Scenario ES3: Supporting Incident Detection & Recognition Operations

The scope of this ES is to monitor the real working environment under normal or extraordinary conditions in order to detect and recognize incidents with equipment or humans that may happen or have just occurred. In this case, a number of different sensors have been used, such as depth sensors, thermal cameras, wearable localization sensors, etc. depending on the exact BSC.

ES3.1: Supporting recognition of incidents in equipment/operations: Incidents occurring in equipment and/or operations at the shopfloor are dedicted. The system automatically monitors a process, on-the-fly checks the real-life data at real-time, detects potential problems and sends alert to specified users (employees responsible for this process).

ES3.2: Recognizing Incidents with Humans on the Shop-Floor: human movements in the shop-floor are monitored, in order to detect and recognize incidents where humans are involved (falls, collisions, etc.). The end-users are timely informed by the system with alerts or warnings, so that the appropriate mitigation actions are taken.

Evaluation Scenario ES4: Offering "On-the-Job" Training Services

Many studies proved that assembly applications can benefit substantially from the improved memorization attainable via AR and, the improved memorization can shorten the training time of new employees. Enhancement of long-term memory is also a strong positive factor in the understanding and retention of assembly or repair sequences, procedures and other information. In SatisFactory, the AR technologies applied in the assistance to the worker during his/her normal work are also used during the "on-the-job" training activities.

ES4.1 Training environment set-up: Set-up of the environment for the guidance during the Mounting phase when the AR supporting tool is set-up.

ES4.2 Training support – Execution: The execution stage deals with the support to the worker during the on-the job activity.

ES4.3 Training support – Data Analysis: The results obtained during the execution are analysed. The tool creates comparisons with previously accumulated data and provides input for the individual or trainee groups statistical analysis.

Evaluation Scenario ES5: Gamification and Collaboration Tools Usage

The scope here is to evaluate how much SatisFactory tools increase the satisfaction of workers. This is evaluated on the basis of Collaboration and Gamification. The aim of the collaboration tool is to improve the social collaboration between workers and as a consequence to result in better satisfaction. The aim of the gamification tool is to motivate unpopular tasks better and as a consequence, to decrease dissatisfaction.

ES5.1: Gamification Tools Usage: Workers and supervisors can collect points by performing certain tasks. These can be unpopular but also popular/accepted actions. The cumulative points of the groups are publicly displayed and, at the same time, each worker can access his/her individual points on which basis he/she can achieve better avatars, badges or company rewards. As far as Social Collaboration is concerned, gamified procedures have been deployed where workers can achieve points, badges and level up (using Tips&Tricks, voting for a useful answer or for an important question, posting of material etc.). All gamified actions are combined with the aforementioned awards, points, badges and levels, via rules which determine how many points will be gained from triggered actions and afterwards at which point badges and levels are achieved.

ES5.2: Collaboration Tools Usage: This scenario evaluates whether the collaboration between workers and managers can be improved by installing a support tool for suggestions for improvement process. Workers can submit suggestions for improvement (e.g. process improvements, wellbeing), which are sent to a decider and the decider's decision and

justification is returned. Moreover, in the Social Collaboration tool both workers and managers can benefit from its use (more pleasant and friendly environment where exchange of knowledge will pass from experienced employees to new ones, online community sharing same interests, interaction with co-workers etc.). Additionally, a Questions & Answers tool is available for the users to increase their knowledge and enhance their skills. This platform additionally is supported by gamification concepts in order to create a more attractive environment for employees.

3.2.2 Evaluation Process and Map

As aforementioned, the goal of the evaluation is to actually evaluate the **SatisFactory products** from the user point of view. The list of the SatisFactory single exploitable products shown below has been made available in D7.1 “Market Analysis and Exploitation Strategy” and the Business Scenarios in D1.2 “Use Case analysis and application scenarios description”.

Table 2 SatisFactory products for evaluation

No	Exploitable product
1	Semantics and Context-aware knowledge shop floor analysis engine
2	Real-time localization of workers, tools and machines
3	Dynamic Re-adaptation of Production Facilities
4	HR workload balancing toolkit (Incident management)
5	Feedback Engine (incident detection)
6	On-the-job training toolkit
7	Hardware HMI, HMD
8	Integrated shop floor DSS
9	Gamification/Collaboration platform for manufacturing enterprises
10	Middleware for Smart Factories
11	Smart Sensor Network for Industrial Applications

The connection of the BSCs, ESs, ETs and SatisFactory products is presented in the following table, as in D5.2, in what has been known within the project as the **Evaluation Map**. This connection is of interest and it is considered, even if it is implemented in a partial way in the complete context of the respective BSCs.

Table 3 Connection of the BSCs, ESs, ESs, ETs and SatisFactory products

ET	BSC CPERI	BSC COMAU	BSC SUNLIGHT	SatisFactory products
ET1: Automated Support for Assembly Operations	BSC-5.1, BSC-5.3	BSC-1.1, BSC-1.2	BSC-3.1	1, 3, 5, 8, 10, 11
ET2: AR supported assembly operations	BSC-5.2	BSC-1.1, BSC-1.2	BSC-4.1	1, 2, 6, 7, 10
ET3: Corrective Maintenance, Re-adaptation & HR Workload Balancing	BSC-5.1	BSC-2.1	BSC-3.1	1, 2, 3, 4, 5, 8, 10, 11
ET4: Preventive Maintenance, Re-adaptation & HR Workload Balancing	BSC-5.3	BSC-2.1	BSC-3.1	1, 2, 3, 4, 5, 8, 10
ET5: Collaboration in Shop Floor Working Environment	BSC-5.1, BSC-5.3	BSC-1.1, BSC-1.2	BSC-3.1 BSC-4.1?	1, 9, 10, 11
ET6: Supporting recognition of incidents in equipment/ operations	BSC-5.1	BSC-1.1, BSC-1.2	BSC-4.2	1, 2, 3, 10, 11
ET7: Recognition of Incidents with Humans on the Shop-Floor	BSC-6.1	BSC1-1, BSC-1.2		1, 2, 3, 10, 11
ET8: On-the-job training in assembly operations	BSC-5.2	BSC-1.1, BSC-1.2	BSC-4.3	1, 6, 7, 10
ET9: Gamification in Shop Floor Working Environment	BSC-5.1, BSC-5.3	BSC-1.1, BSC-1.2	BSC-3.1, BSC-4.1, BSC-4.3	1, 9, 10, 11

The **Evaluation Process** itself has been comprised by 3 dedicated workshops and 2 Data Collections (DCs) combined with an Information Session at each shop floor; one after the first iteration of the deployment and another after the completion of the demonstrators.

The scope of the **Workshops** was to inform the involved personnel that need to coordinate the Data Collection from the three shop floors in the adopted approach and to demonstrate the usage of the tools to be used. These workshops were performed in the form of webinars and the exact time for them was decided according also to the course of developments and deployment at the three shopfloors. The scope of the **Information Sessions** was to provide information on the course of the developments and the SatisFactory tools. The **Data Collection** was also paired with a hands on demonstration for the deployed solutions at each shopfloor. Participants provided their feedback using the Instruments developed and presented in D5.2 (Questionnaires and Impact Check Lists for workers and supervisors).

4. RESULTS CONSOLIDATION

An overview of the Evaluation Framework of SatisFactory that has been used at COMAU and SUNLIGHT – as well as at CERTH/CPERI - is useful at this point. It is comprised by five Evaluation Scenarios and there are different questionnaires for the Workers and the Decision Makers.

In each questionnaire, there are two sections; the first being the general evaluation questions (SUS questionnaire) and the second being the SatisFactory specific evaluation questions (according to the 5 criteria: Usability, Knowledge Integration, Working Experience, User Acceptance and Overall Impact).

People responding to the questionnaires may choose from five (5) available responses:

- Strongly Agree
- Agree
- Neither agree nor disagree
- Disagree
- Strongly Disagree

For the general evaluation the first two options that convey a positive opinion have been grouped and the last two options that convey a negative opinion have been also grouped.

4.1 EVALUATION RESULTS AT COMAU

Two measurements were carried out at COMAU, for which we present detailed charts below. To improve readability and to avoid interpreting each chart separately, we will comment each specific measurement only where it is necessary or to highlight important points. The age, experience, and years of employment data are presented as charts for information purposes only. The distribution of these characteristics among participants is similar to the real distribution in the work force, therefore no special remarks need to be done on each chart separately.

The limited number of responses leaves room for a wide margin of error, however several of the changes between the measurements are so large that they leave no doubt for the general trend. We comment on these as necessary.

4.1.1 Evaluation Scenario 1 Results

It is reminded that the Evaluation Scenario 1 (Supporting Assembly Operations), is comprised by two scenarios (ES1: Automated support for assembly operations and ES2 AR supported assembly operations). The data collection is done using two questionnaires (ET1 Automated Support for Assembly Operations and ET2 AR Supported Assembly Operations).

4.1.1.1 ES1 Workers' Results

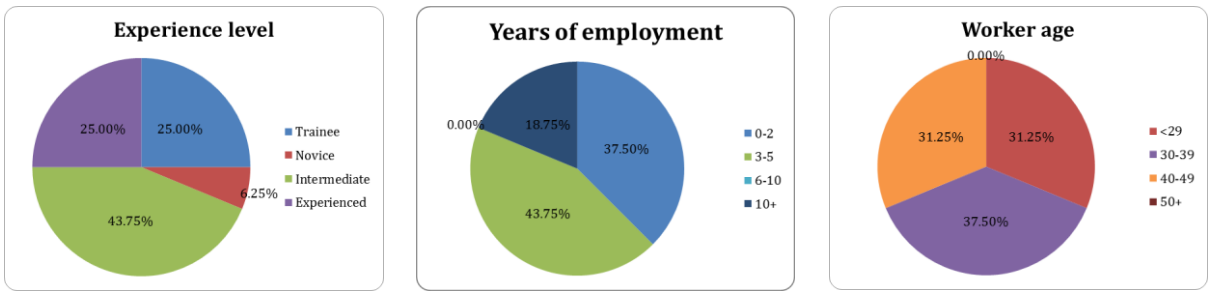
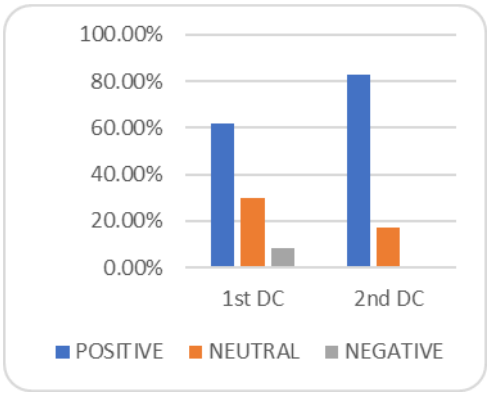
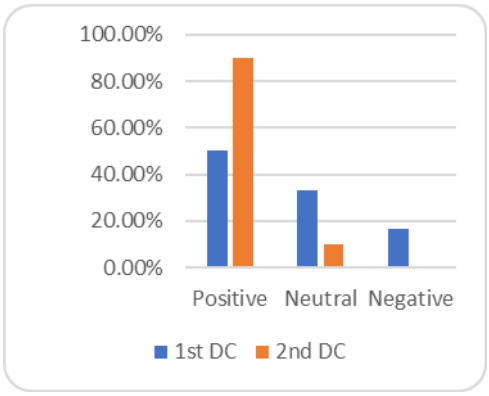


Figure 13 ES1-Workers, COMAU

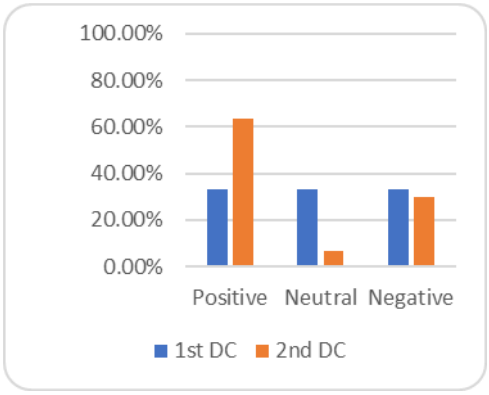
During the 1st Data Collection period at COMAU no feedback was collected for ET1.1 and 6 workers responded to ET2.1, while in the 2nd Data Collection period 20 workers responded to ET1.1 and 20 workers responded to ET2.1.



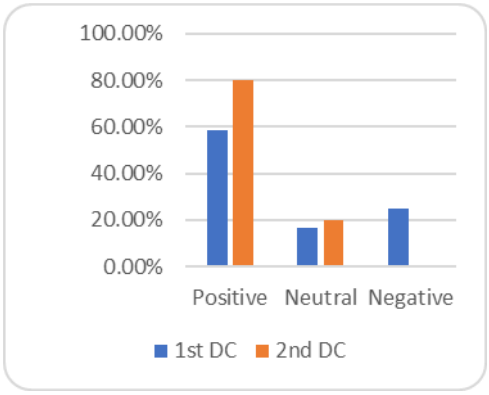
(a) General Evaluation



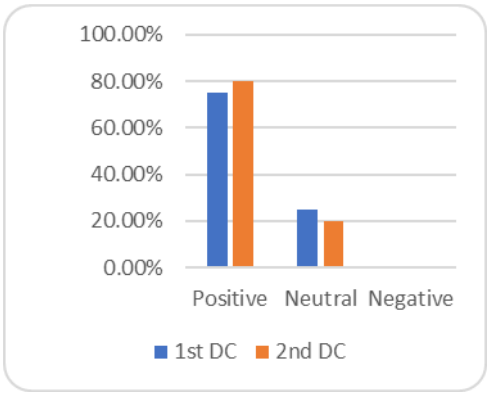
(b) Usability



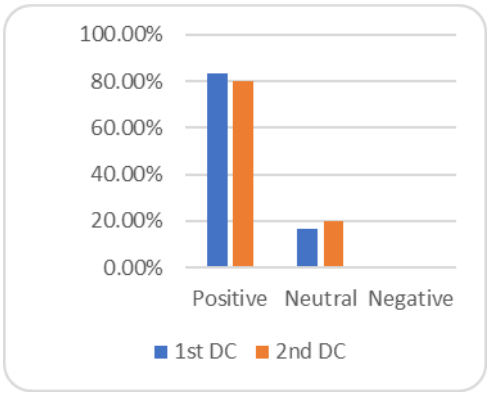
(c) Knowledge Integration



(d) Working Experience



(e) User Acceptance



(f) Overall Impact

Figure 14 ES1-Workers, COMAU: Supporting Assembly Operations

The first data collection is marked by a positive attitude generally, but with about half the people being doubtful and not feeling that their way of working at the time was usable.

That perception has changed in the second evaluation. There are no negative answers, whereas the neutral voices have massively shifted to reporting a positive impact i.e. workers were successfully shifted to a positive or neutral standing. In particular, the overall impact has only positive voices to it. Knowledge integration could be improved, since about a quarter of the people do not see an improvement in it.

4.1.1.2 ES1 Decision Makers' Results

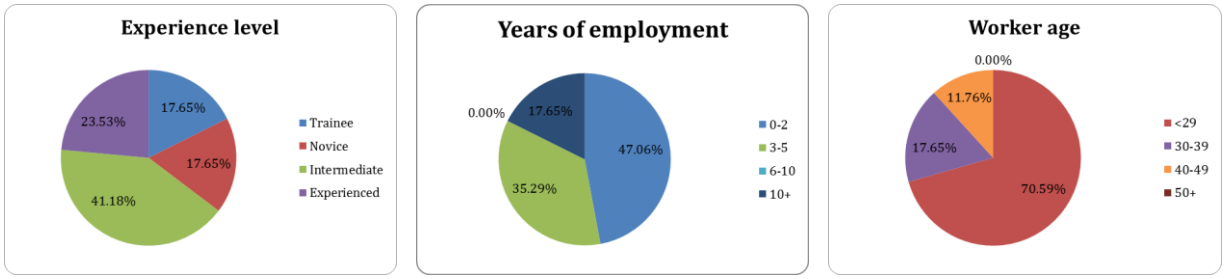
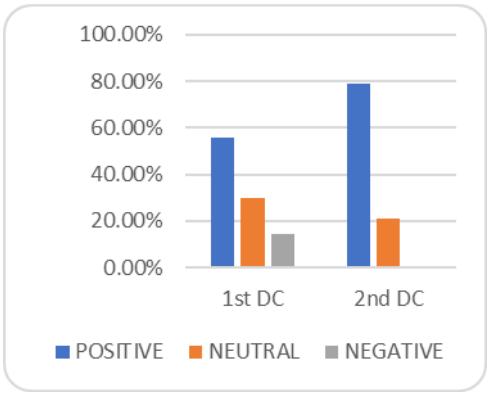
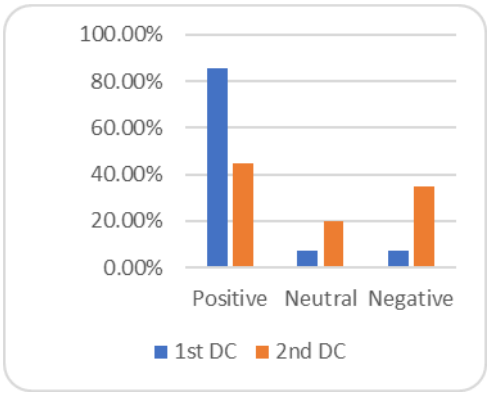


Figure 15 ES1 Decision Makers, COMAU

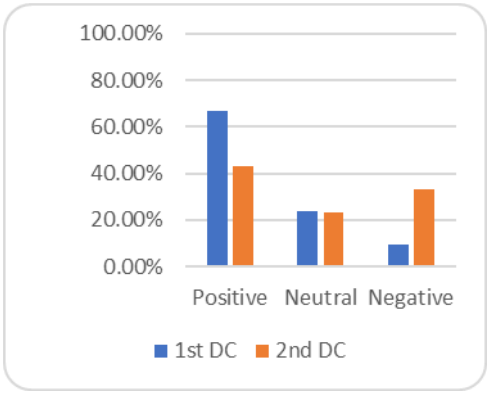
During the 1st Data Collection period at COMAU no feedback was collected for ET1.2 and 7 decision makers responded to ET2.2, while in the 2nd Data Collection period 20 decision makers responded to ET1.2 and 20 decision makers responded to ET2.2.



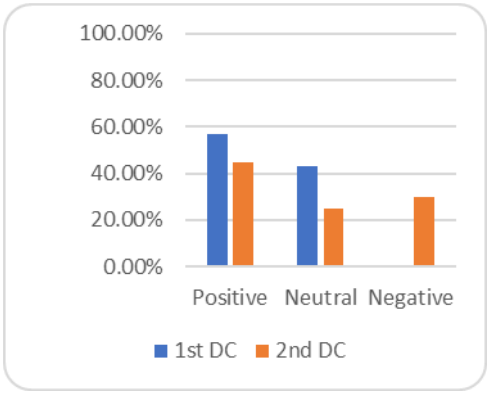
(a) General Evaluation



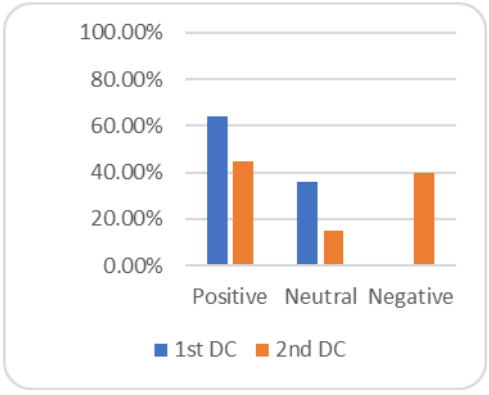
(b) Usability



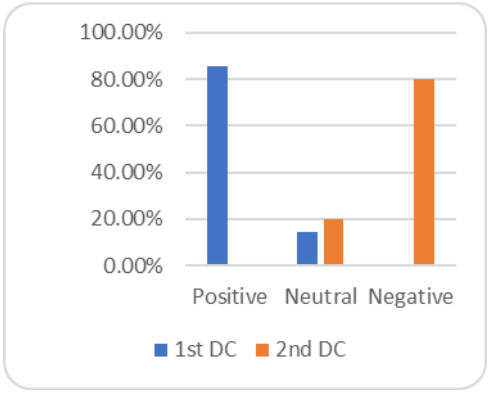
(c) Knowledge Integration



(d) Working Experience



(e) User Acceptance



(f) Overall Impact

Figure 16 ES1-Decision Makers, COMAU: Supporting Assembly Operations

The mix of respondents for this scenario reflects both the training and age distribution typical of the factory shop floor. The first data collection, shows that all indicators are relatively

positive or neutral, except for working experience where a considerable proportion of users are neutral in their opinion.

The comparison between the two data collections reveals that overall the pilot implementation pushed the opinion towards the positive end of the scale, but the detailed metrics are once again negative, as presented .

Thus, there is a marked decline in usability, working experience, knowledge integration, and user acceptance. The most striking change is that in the overall impact of the pilots: most people consider them to have no impact at all. The results are puzzling, considering the general positive evaluation. The reasons for this change of opinion have to be studied more in depth.

4.1.2 Evaluation Scenario 2 Results

The Evaluation Scenario 2 (Offering Maintenance, Re-adaptation & HR Workload Balancing Services) is comprised of two scenarios (ES2.1 Corrective Maintenance, Re-adaptation & HR Workload Balancing and ES2.2 Preventive Maintenance, Re-adaptation & HR Workload Balancing). The data collection is done using two questionnaires (ET3 Corrective Maintenance, Re-Adaptation & HR Workload Balancing and ET4 Preventive Maintenance, Re-Adaptation & HR Workload Balancing).

4.1.2.1 ES2 Workers' Results

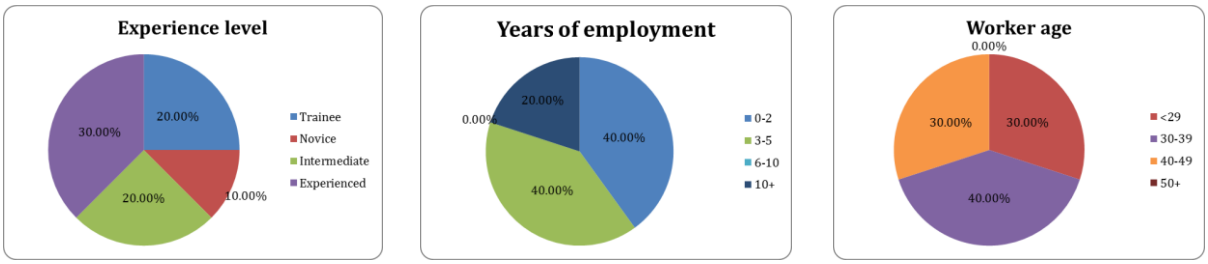
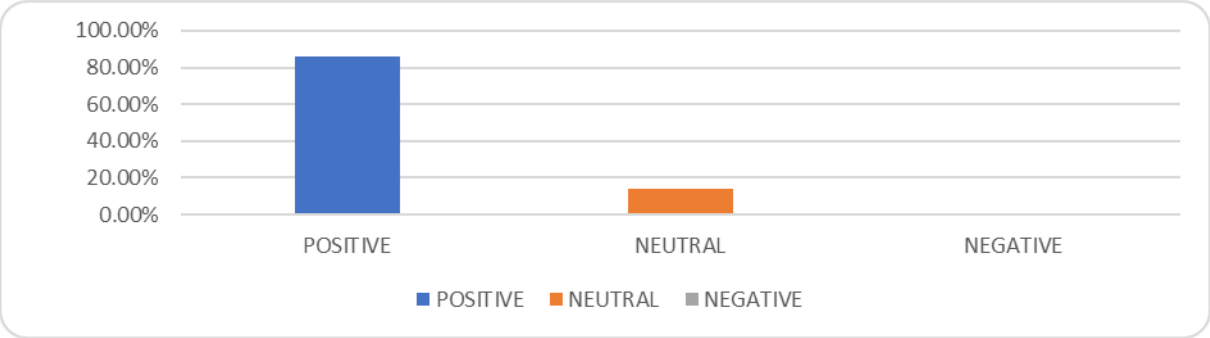
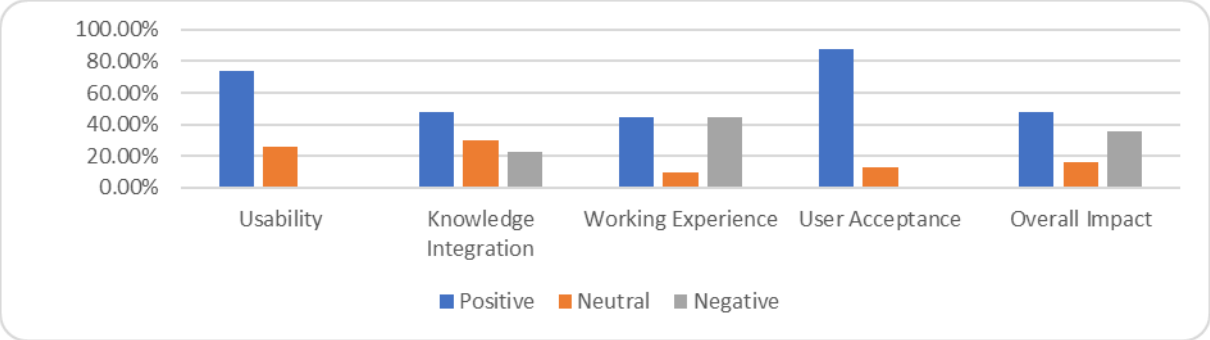


Figure 17 ES2 Workers, COMAU

During the 1st Data Collection period at COMAU no feedback was collected for ET3.1 and for ET4.1, while in the 2nd Data Collection period 20 workers responded to ET3.1 and 20 workers responded to ET4.1.



(a) General Evaluation



(b) Specific evaluation

Figure 18 ES2-Workers, COMAU: Offering Maintenance, Re-adaptation & HR Workload Balancing Services

It is encouraging to see the positive user acceptance results in the second evaluation, but 40% of the users reporting a negative working experience overshadows that result. We believe that the positive general evaluation resulted from the user acceptance and possibly a Hawthorne effect of the pilots, but that it needs to be investigated why the working experience in the second measurement was not satisfactory for almost half the users. One possible explanation is that COMAU already had systems and procedures in place, which have been changed in the pilots, giving rise to a negative perception while people get used to the new system.

4.1.2.2 ES2 Decision Makers' Results

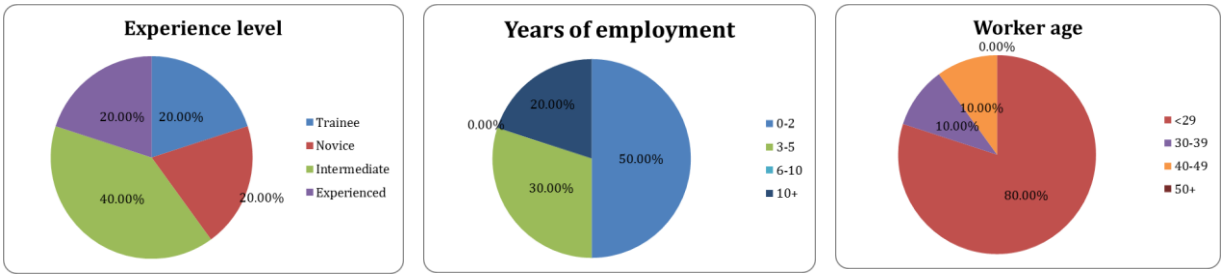
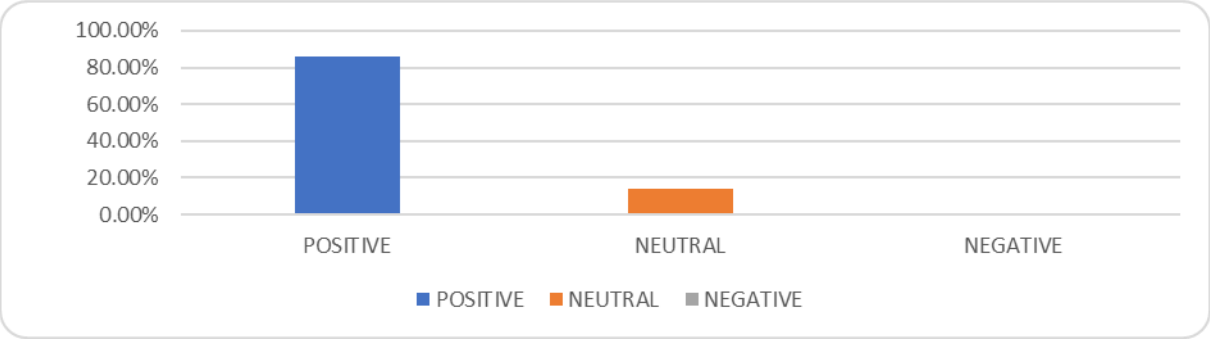
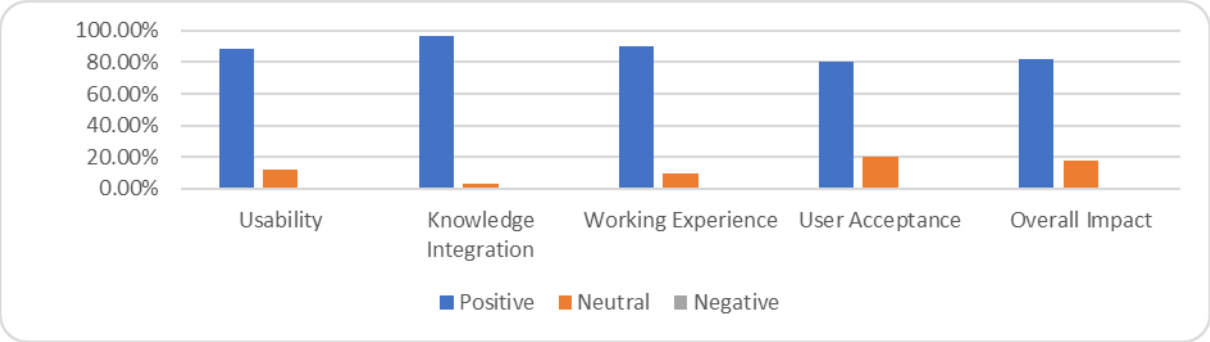


Figure 19 ES2 Decision Makers, *COMAU*

During the 1st Data Collection period at COMAU no feedback was collected for ET3.2 and for ET4.2, while in the 2nd Data Collection period 20 decision makers responded to ET3.2 and 20 decision makers responded to ET4.2.



(a) General Evaluation



(b) Specific evaluation

Figure 20 ES2-Decision Makers, COMAU: Offering Maintenance, Re-adaptation & HR Workload Balancing Services

In stark contrast to the workers, the managers see ES2-DM as largely successful. The discrepancy between manager's score and the worker's score is all the more worrying, since it hints that managers are satisfied with the results and are thus blind to the workers' concerns. The project should better analyse the causes of this discrepancy in order to exclude the possibility that the systems have focused too much on managers and have ignored the satisfaction of workers.

4.1.3 Evaluation Scenario 3 Results

It is reminded that the Evaluation Scenario 3 (Supporting Incident Detection & Recognition Operations), is comprised by two scenarios (ES3.1: Supporting recognition of incidents in equipment/operations and ES3.2 Recognizing Incidents with Humans on the Shop-Floor).

The data collection is done using two questionnaires (ET6 Recognition of incidents in equipment/operations and ET7 Recognition of incidents with humans on the shop-floor).

4.1.3.1 ES3 Workers' Results

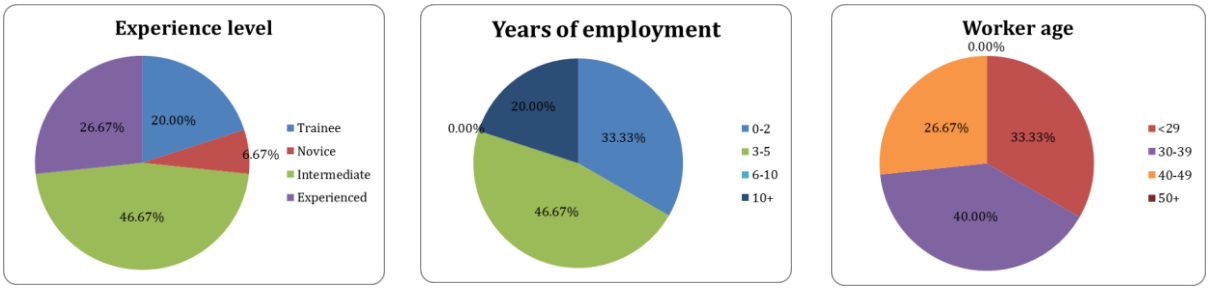
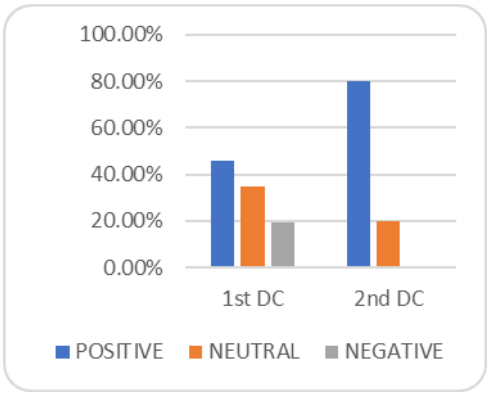
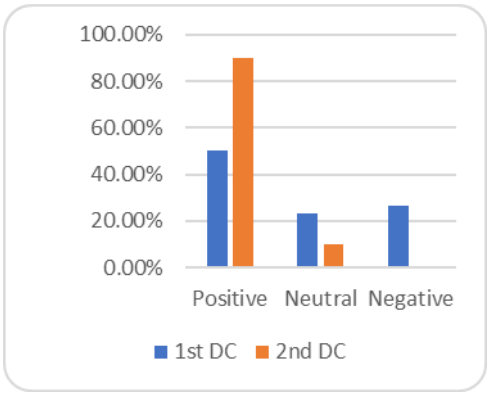


Figure 21 ES3 Workers, *COMAU*

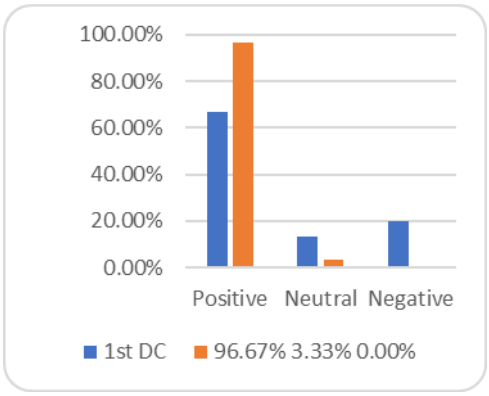
During the 1st Data Collection period at COMAU, 5 workers responded for ET6.1 and 5 workers responded to ET7.1, while in the 2nd Data Collection period 20 workers responded to ET6.1 and 20 workers responded to ET7.1.



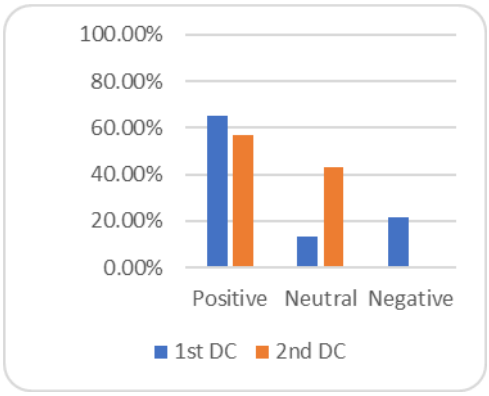
(a) General Evaluation



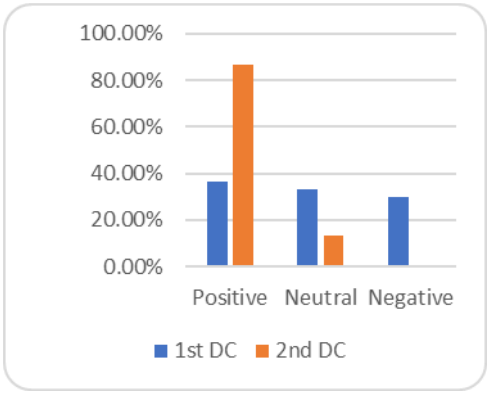
(b) Usability



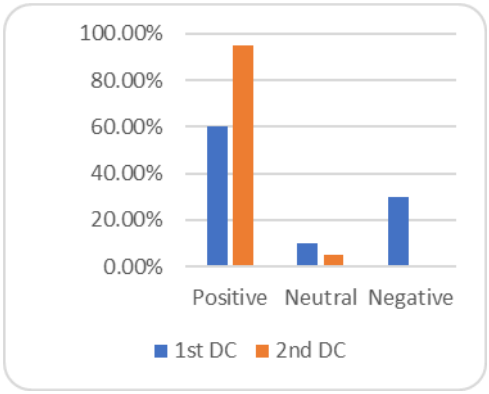
(c) Knowledge Integration



(d) Working Experience



(e) User Acceptance



(f) Overall Impact

Figure 22 ES3-Workers, COMAU: Supporting Incident Detection & Recognition Operations

ES3 is the first scenario where SatisFactory concepts have been clearly successful. The second data collection reveals no negative opinions, while the number of neutral responders has also decreased in favour of more satisfied users. Most metrics also show an increase in the second evaluation except for working experience.

As already hinted, it is encouraging that all metrics are positive in the second evaluation. It is however disconcerting to see that working experience has taken a step back. The changes are fortunately not into the negative domain, but the increased number of people having a neutral opinion should be cause for alarm, especially when they are compared to the decision makers' results above. The same concern as for ES2 is plausible: whether the system focused too much on satisfying management to the detriment of the workers' satisfaction.

4.1.3.2 ES3 Decision Makers' Results

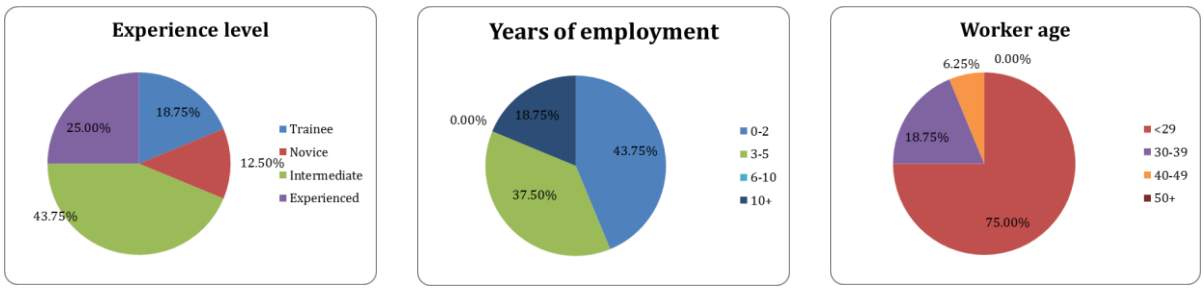
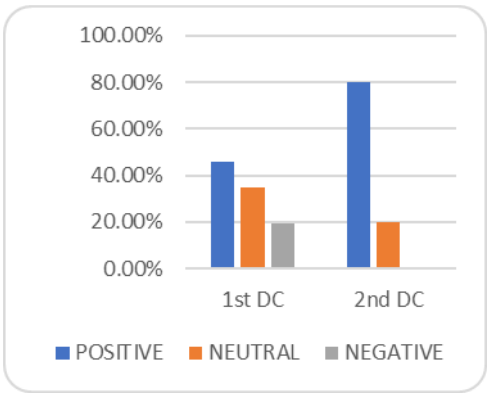
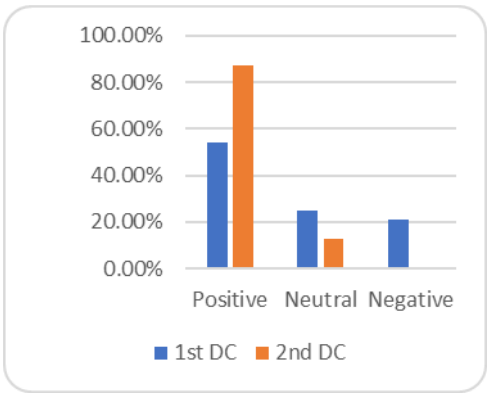


Figure 23 ES3 Decision Makers, *COMAU*

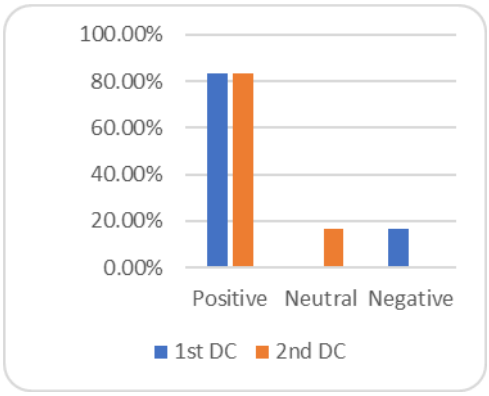
During the 1st Data Collection period at COMAU 6 decision makers responded for ET6.2 and 6 decision makers responded to ET7.1, while in the 2nd Data Collection period 12 decision makers responded to ET6.2 and 12 decision makers responded to ET7.2.



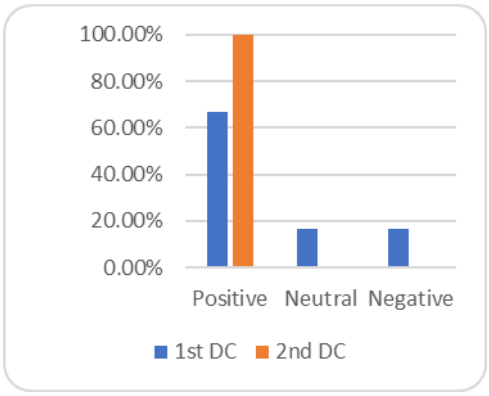
(a) General Evaluation



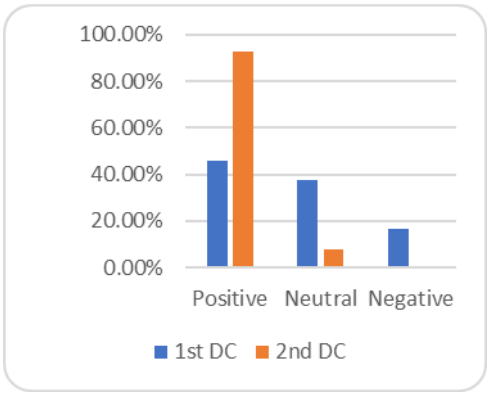
(b) Usability



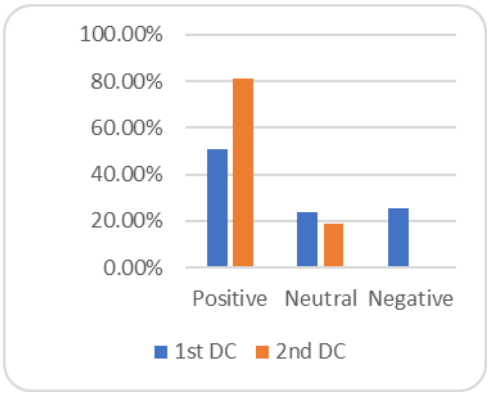
(c) Knowledge Integration



(d) Working Experience



(e) User Acceptance



(f) Overall Impact

Figure 24 ES3-Decision Makers, COMAU: Supporting Incident Detection & Recognition Operations

As already hinted in the previous section, and as the charts show, the managers have a positive opinion after the ES3 scenario evaluation. The SUS metrics have all improved, in particular the working experience, for which decision makers have a 100% positive opinion as compared to less than 60% of the workers. The reason for this discrepancy needs to be investigated further.

4.1.4 Evaluation Scenario 4 Results

Evaluation Scenario 4 (Offering "On-the-Job" Training Services) consists of three scenarios (ES4.1 Training environment set-up, ES4.2 Training support – Execution and ES4.3 Training support – Data Analysis). The data collection obtained within this scenario was based on one questionnaire, named On-the-job training in assembly operations (ET8.1 for worker and ET8.2 for decision maker).

4.1.4.1 ES4 Workers' Results

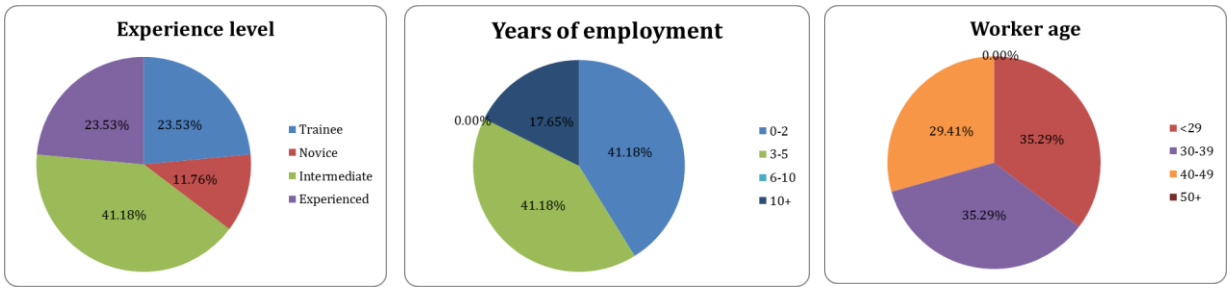
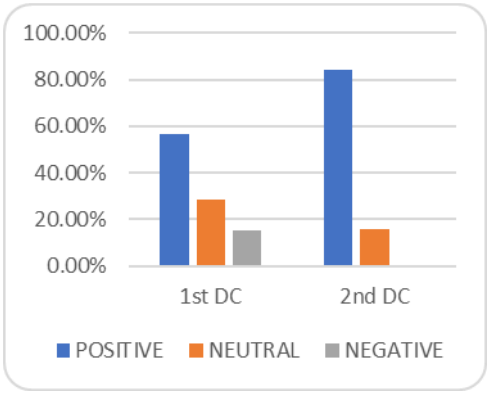
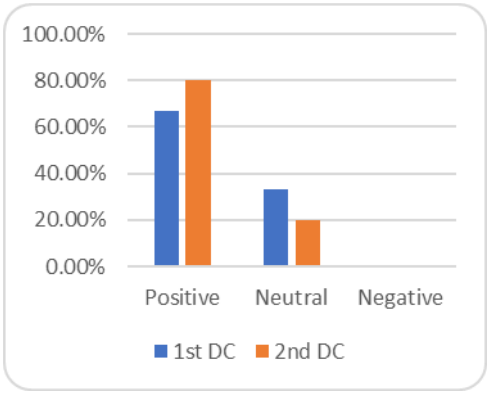


Figure 25 ES4 Workers, COMAU

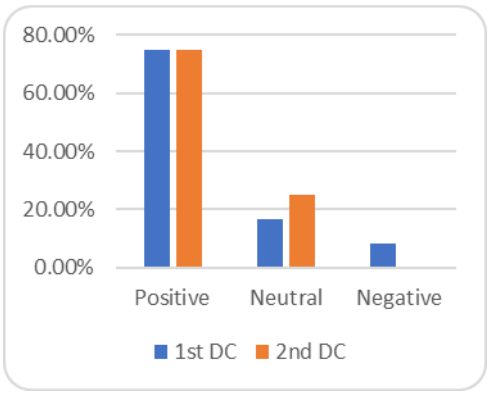
During the 1st Data Collection period at COMAU 7 workers responded for ET8.1, while in the 2nd Data Collection period 20 workers responded to ET8.1.



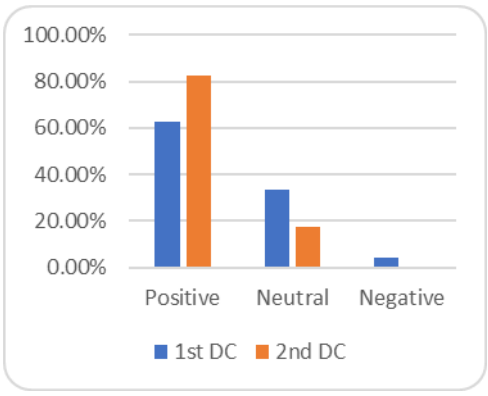
(a) General Evaluation



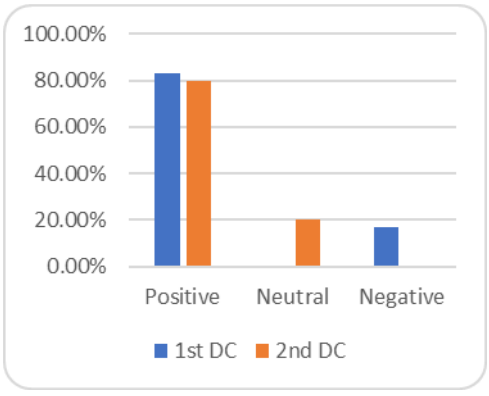
(b) Usability



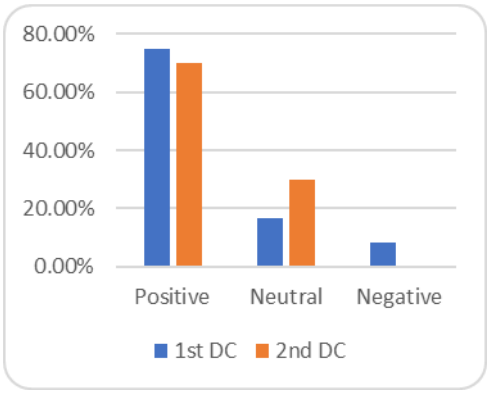
(c) Knowledge Integration



(d) Working Experience



(e) User Acceptance



(f) Overall Impact

Figure 26 ES4-Workers, COMAU: Offering “On-the-Job” Training Services

4.1.4.2 ES4 Decision Makers' Results

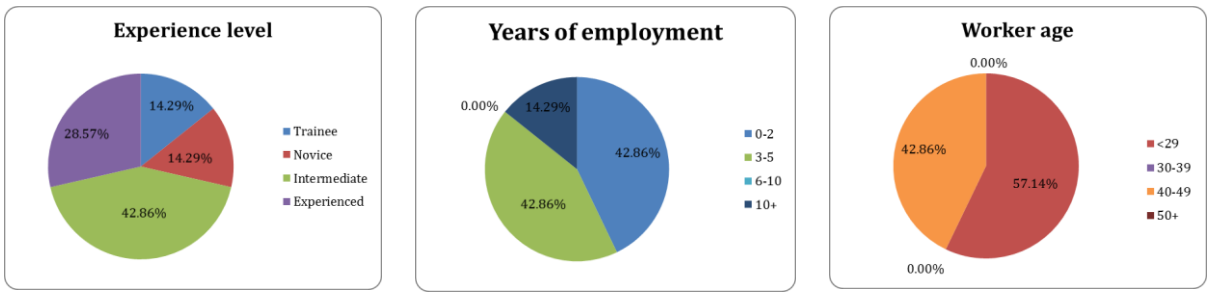
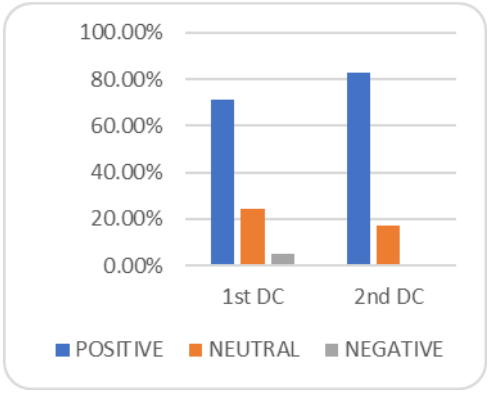
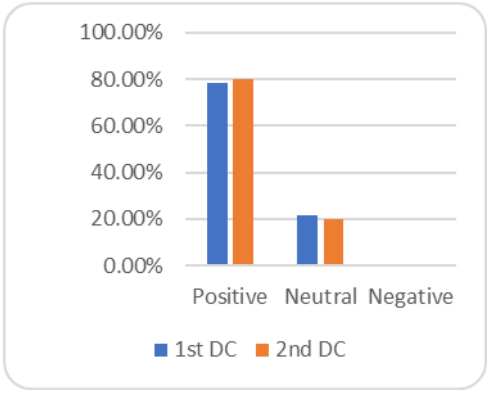


Figure 27 ES4 Decision Makers, COMAU

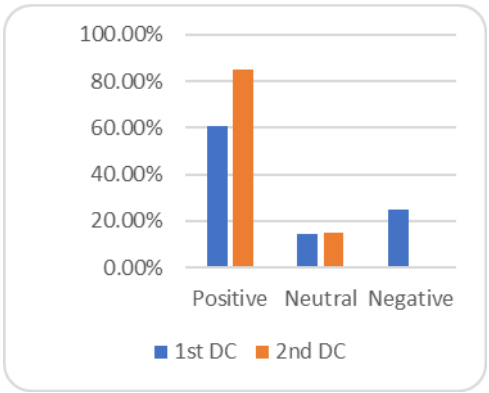
During the 1st Data Collection period at COMAU no feedback collected for ET8.2, while in the 2nd Data Collection period 14 decision makers responded to ET8.2.



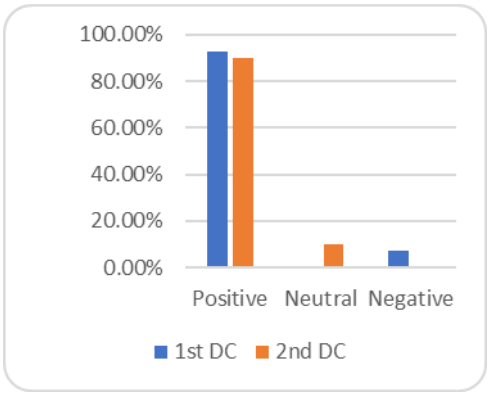
(a) General Evaluation



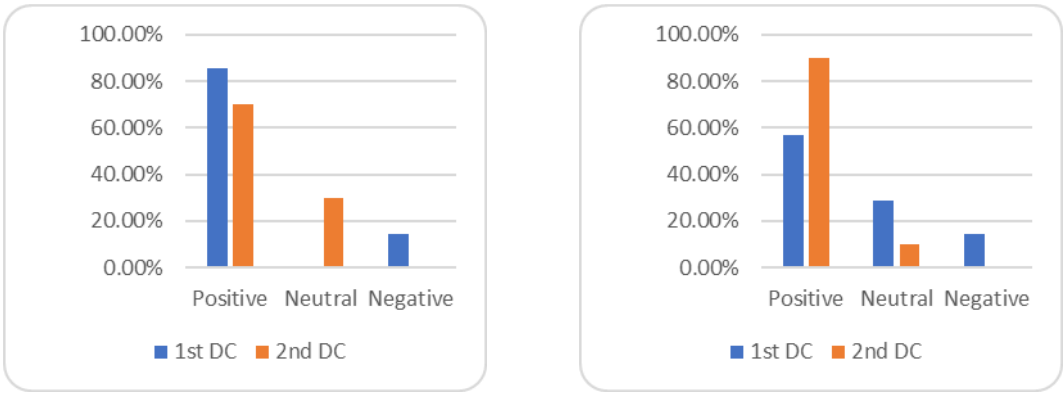
(b) Usability



(c) Knowledge Integration



(d) Working Experience



(e) User Acceptance (f) Overall Impact

Figure 28 ES4-Decisio Makers, COMAU: Offering "On-the-Job" Training Services

The evaluation of the fourth scenario is generally positive, showing improvement in most metrics and does not give rise to any contradiction. In particular, the worker's and decision maker's scores in ES4 are compatible with each other. The User acceptance decrease in the second measurement is within the measurement error range. Furthermore, even if the decrease were statistically significant, the user acceptance dimension may hint at problems with the implementation and not with the concept, as was the case with some of the previous scenarios.

4.1.5 Evaluation Scenario 5 Results

Evaluation Scenario 5 (Gamification and Collaboration Tools Usage) consists of two scenarios (ES5.1: Gamification Tools Usage and ES5.2: Collaboration Tools Usage). The data collection obtained within this scenario was based on two questionnaires, Gamification in shop floor working environment and Collaboration in shop floor working environment, for workers (ET9.1 and ET5.1) and for decision makers (ET9.2 and ET 5.2)

4.1.5.1 ES5 Workers' Results

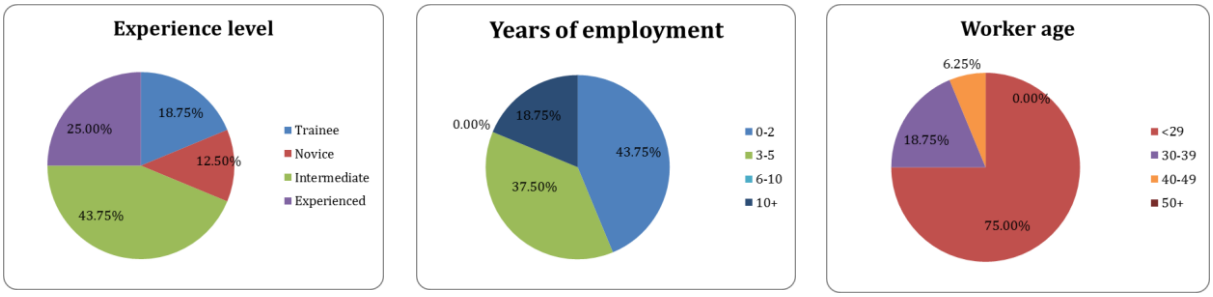
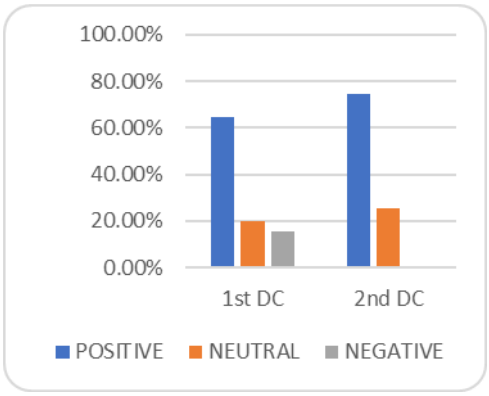
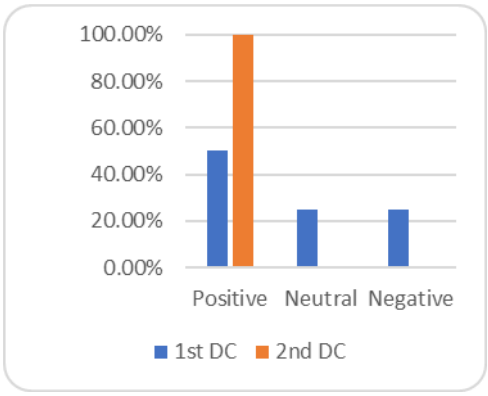


Figure 29 ES5 Workers, COMAU

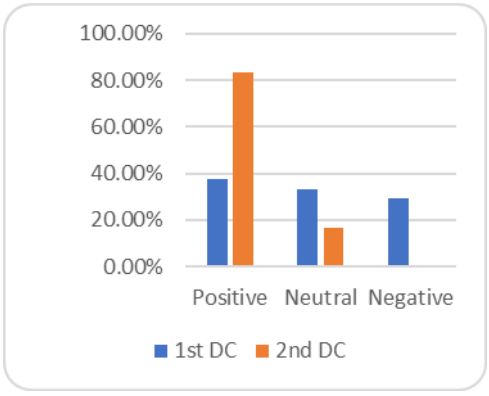
During the 1st Data Collection period at COMAU 6 workers responded for ET5.1 and 5 workers responded to ET9.1, while in the 2nd Data Collection period 20 workers responded to ET5.1 and 20 workers responded to ET9.1.



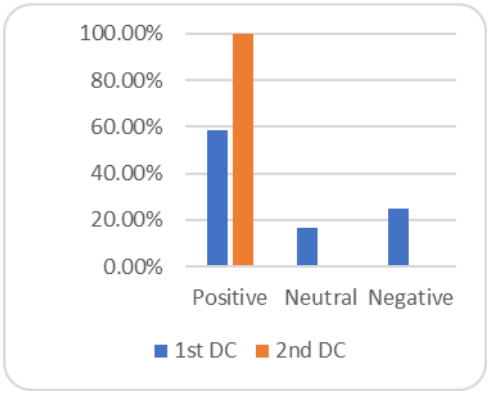
(a) General Evaluation



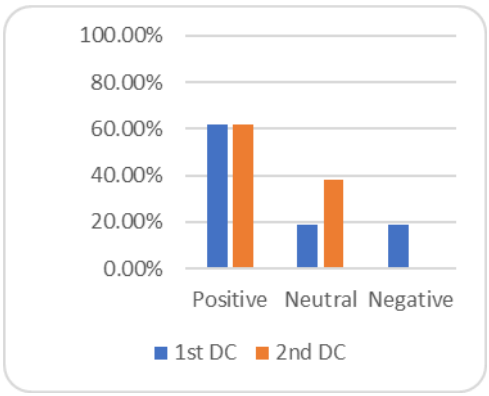
(b) Usability



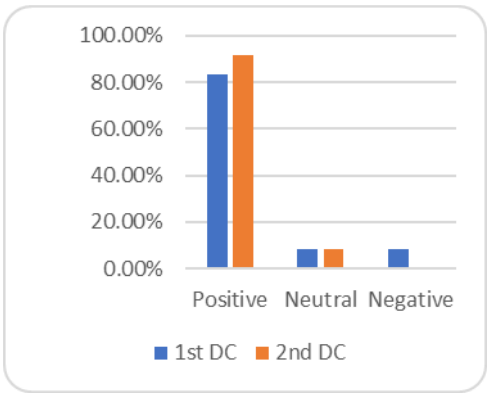
(c) Knowledge Integration



(d) Working Experience



(e) User Acceptance



(f) Overall Impact

Figure 30 ES5-Workers, COMAU: Gamification and Collaboration Tools Usage

ES5 is the first scenario where all the metrics have improvement and there is no doubt and no questions raised about the validity of the approach. Thus, the general evaluation improved from 10% negatives to 0, and from 73% to 85% positive evaluation. The numbers, show, within the limits imposed by the number of participants, that the evaluation scenario was successfully carried out. Of particular importance is the huge increase in the work experience and in knowledge integration scores, which are ultimately the aim of the Satisfactory project.

4.1.5.2 ES5 Decision Makers' Results

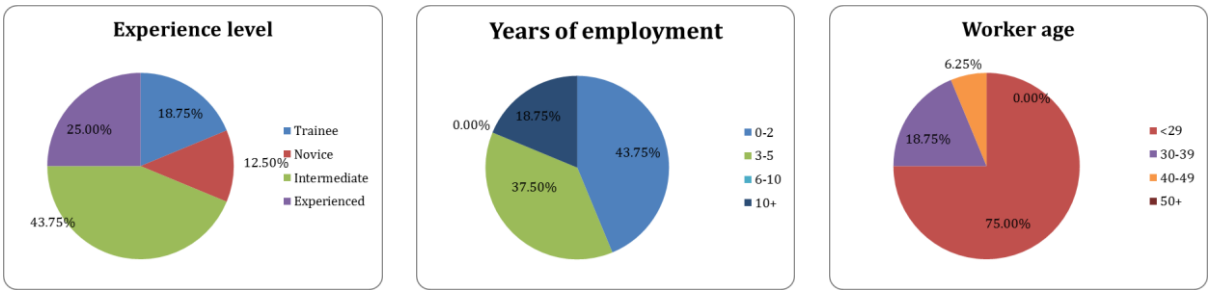
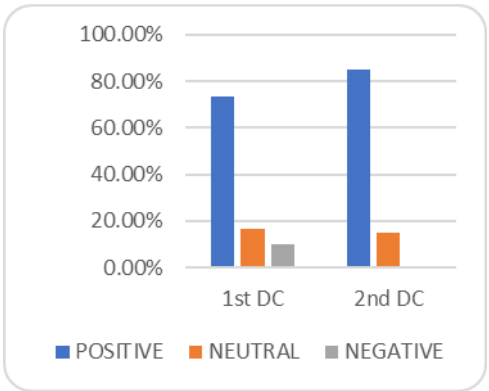
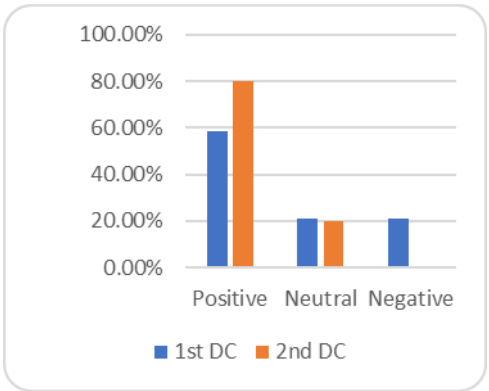


Figure 31 ES5 Decision Makers, COMAU

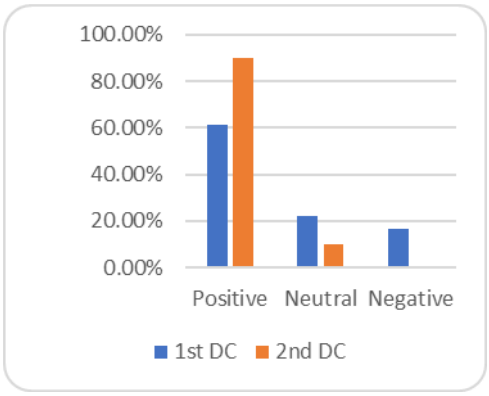
During the 1st Data Collection period at COMAU 6 decision makers responded for ET5.2 and 5 decision makers responded to ET9.2, while in the 2nd Data Collection period 20 decision makers responded to ET5.2 and 20 decision makers responded to ET9.2.



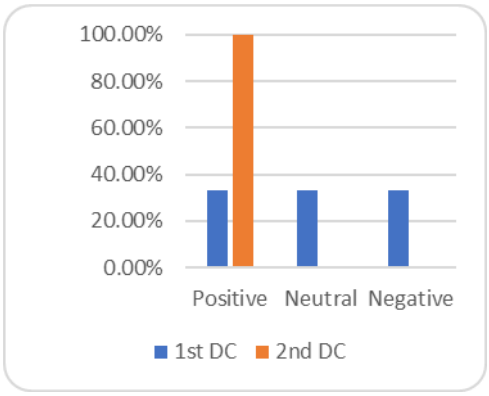
(a) General Evaluation



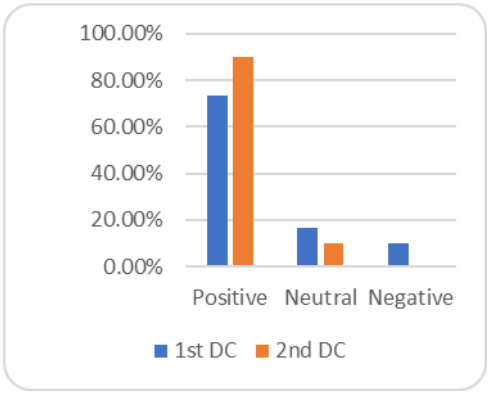
(b) Usability



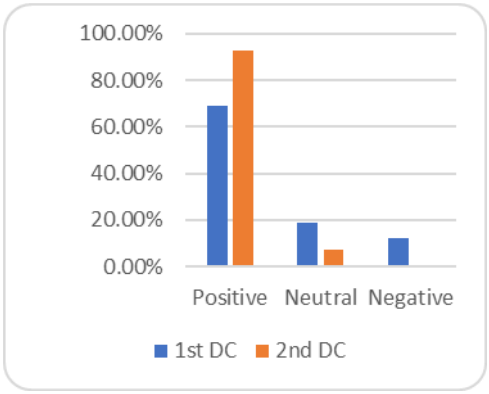
(c) Knowledge Integration



(d) Working Experience



(e) User Acceptance



(f) Overall Impact

Figure 32 ES5-Decision Makers, COMAU: Gamification and Collaboration Tools Usage

The Decision makers' results in the evaluation present no surprises. Just like the workers, decision makers are satisfied with the scenario implementation and, especially for ES5, the knowledge and work experience scores have the highest increase between the two measurements. This matches well with the increase in the workers' scores, hinting that ES5 presents completely and unequivocally positive results.

4.1.6 Impact Check List Results and Analysis

4.1.6.1 Workers' Results

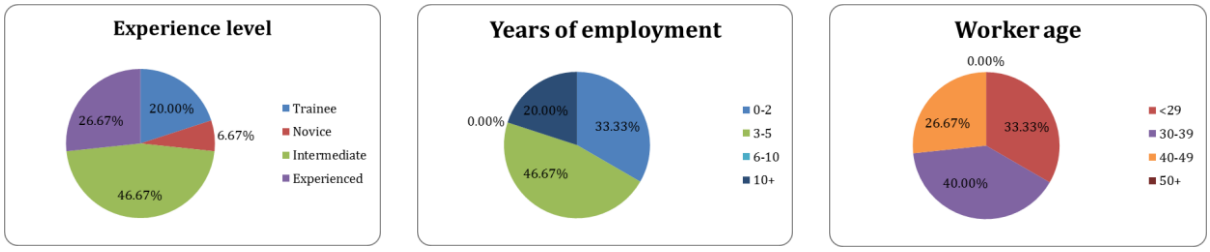
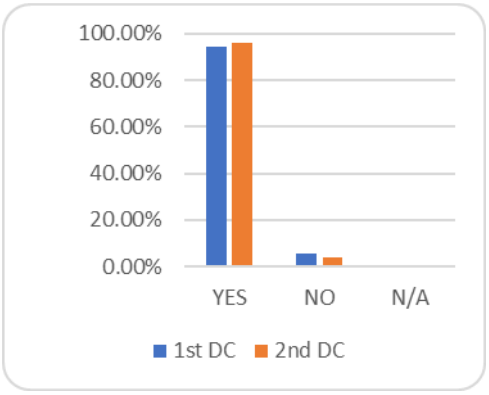
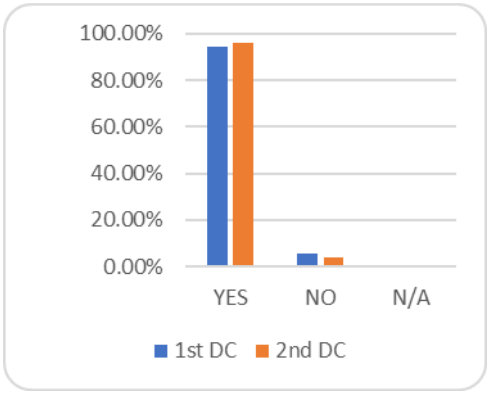


Figure 33 Impact Check List Workers, COMAU

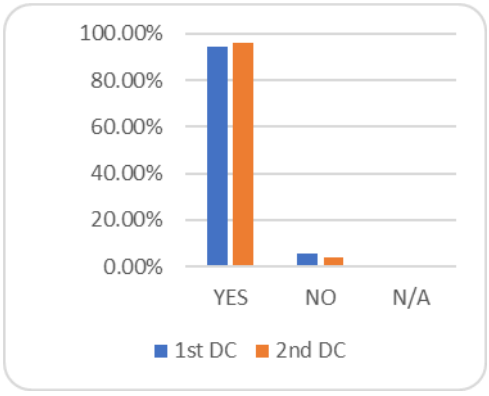
During the 1st Data Collection period at COMAU 6 workers responded for Impact Check List 18 workers responded in the 2nd Data Collection period.



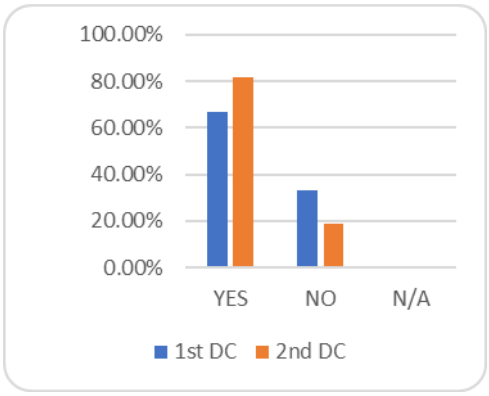
(a) Usability



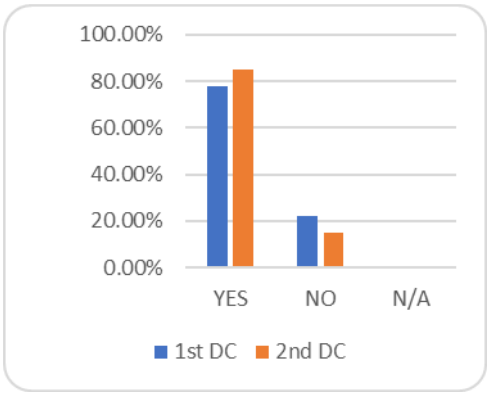
(b) Knowledge Integration



(c) Working Experience



(d) User Acceptance



(e) Overall Impact

Figure 34 Impact Check List -Workers, COMAU

The Impact check list evaluations were not remarkable, i.e. were positive, already at the first data collection. It is encouraging to see that the Satisfactory tools used have not negatively impacted the metrics and have furthermore contributed to a better user acceptance. In particular, usability ratings of 96% are among the highest, especially when compared to software used in the industry.

4.1.6.2 Decision Makers' Results

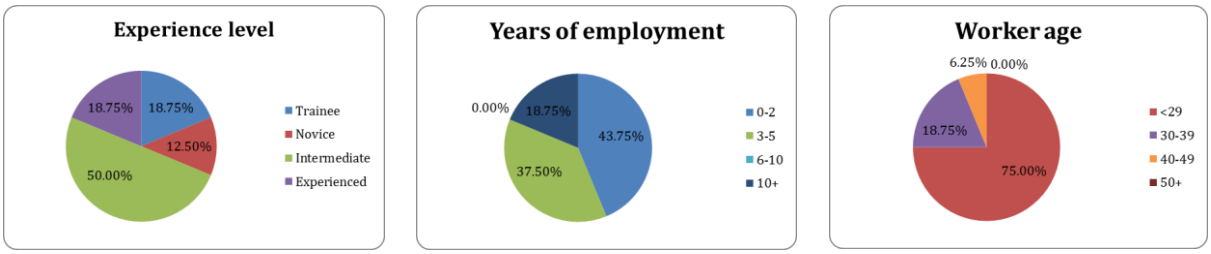
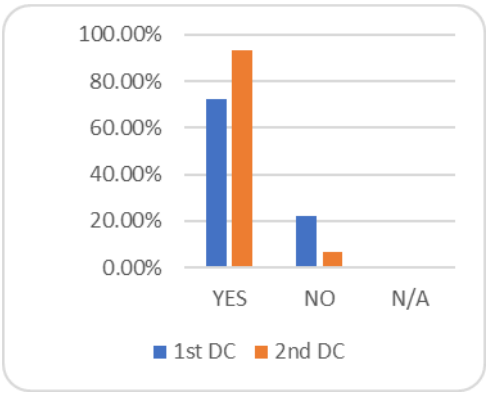
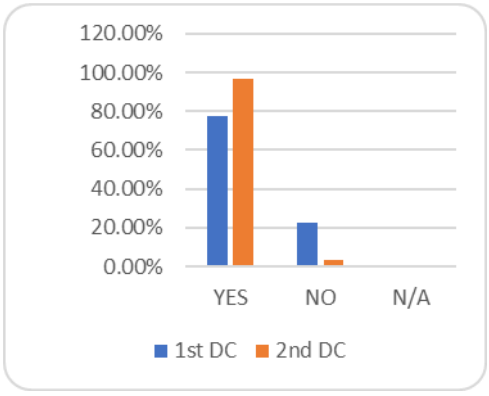


Figure 35 Impact Check List Decision Makers, COMAU

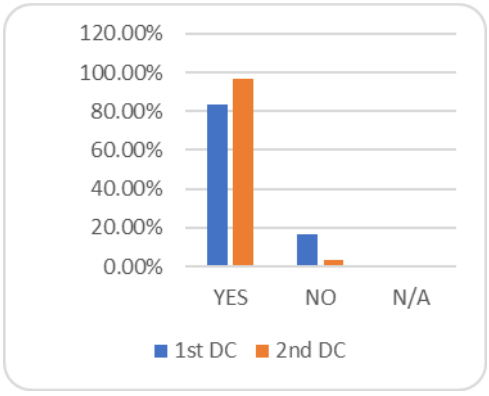
During the 1st Data Collection period at COMAU 8 decision makers responded for Impact Check List 18 decision makers responded in the 2nd Data Collection period.



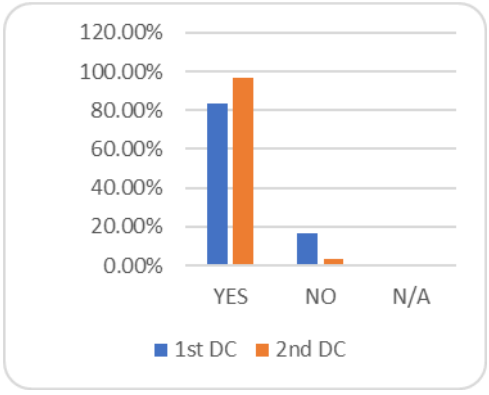
(a) Usability



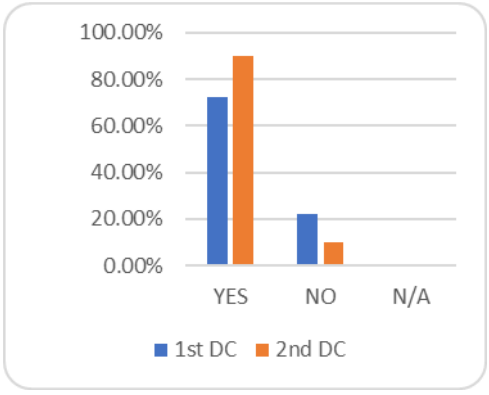
(b) Knowledge Integration



(c) Working Experience



(d) User Acceptance



(e) Overall Impact

Figure 36 Impact Check List -Decision Makers, COMAU

Rather unsurprisingly, just like the workers' results, the managers' evaluation results confirm that the evaluation of the checklists is positive. The scores in the second evaluation have all

gone close to 100%, which is the highest compliment to the project's achievements in this scenario.

4.1.7 Overall Results Assessment

This chapter and the relevant subchapters deal with the final feedback received from COMAU employees involved during the entire project life-cycle or on Data and Information Collection Sessions occasions. The results consolidated above have presented the information collected throughout feedback questionnaires delivered to final users.

Accordingly to Design Thinking methodologies anyway, people that spent their time during project execution observing and interacting directly with COMAU people on the ShopFloor, earned further valuable and practical feedbacks that have turned into products / solutions improvement and into requirements for further developments inside or even outside SatisFactory project horizon, i.e. belonging to exploitation of SatisFactory suite.

This impressive amount of feedback and improvement points / opportunities to be exploited, definitely remarks project success. SatisFactory had a so relevant impact on the company that people spontaneously decided to contribute to the dissemination and consolidation of developments.

4.1.7.1 Conclusions based on SUS

As would be explained later on even in SUNLIGHT – related chapters, a first criterion accordingly to which SatisFactory products and services have been evaluated, starting from data collected through questionnaires, is the SUS (System Usability Scale) Analysis.

SUS Analysis is considered more and more an effective paradigm that can be applied in industrial PoC (Proof of Concepts), since it returns relevant and dependable results even for small sample numbers, typical of PoCs. Basically, as the name itself tells, the systems allows for determination of usability of a solution (mainly software solution), interpreting answers given to questions addressing three main topics: satisfaction of who has tested and / or would use the system, effectiveness of the system for where it has been designed and efficiency when it should be used. Thus, it could be stated that SUS is a user centred method, as the Design Thinking cited shortly above.

SUS is furthermore a way of interpreting results of Likert scales that, per se, are ordinal / rating scales, i.e. each alternative (rate or mark) that should be given per each question has only a priority relationship with previous and following ones. So if the scale foresees 7 possible values, I know e.g. that 6 is worse than 7 but better than 5, without giving any information on the relative distance among point 5, point 6 and point 7; each user could interpret relevant distances in an asymmetric way. It is for this reason that usually Likert scales are accompanied by textual evaluations / graphical depictions. By so is then very difficult to interpret the results and make calculations, while SUS allows to have a robust method of giving value to Likert questionnaires.

First of all, SUS methodologies foresee 10 questions, where 5 express positive statements on usability of the solution; the other 5 are somehow the negation of the previous ones, to

give the result robustness and to definitely discriminate whether the solution is thought to be useful or not. Typical examples of such postulates can be:

1) I would use frequently the presented solution;
2) I felt uncomfortable using the system;
3) I think that the solution is user friendly;
4) The system would not be usable without the support of the developers;
5) All system components are well integrated in the solution;
6) The solution is inconsistent;
7) System usage learning curves would be very steep;
8) I found the solution unnecessarily complex;
9) I am confident in using the system autonomously;
10) The system requires an important background technical knowledge I do not have prior to be used effectively.

The alternatives that can be selected per each question are rates ranging from 1 to 5, with following relevant textual tags (please consider they can also be considered vice versa):

1) Strongly disagree (i.e. the filler does not agree with the statement);
2) Disagree
3) Neutral (neither disagree nor agree)
4) Agree
5) Strongly agree

Usually, ordinal scales with an uneven number of alternatives are discouraged, since people are not pushed, urged to steer toward a definitely good rating (> 3 or other central value) or against a definitely bad comment (< 3); if they are not “risk takers”, they would opt for the central value, always, giving no value to the results of the questionnaire. On the other side, a positive (or negative) evaluation, would have a stronger meaning / impact!

The achieved result per each question is then taken into account by questionnaires analyst; if the grade is positive (> 3) the analyst subtracts 1 to it, or She / He subtracts the rate itself, if it is negative (< 3), to the maximum of the scale, i.e. 5. Obtained value is then multiplied by 2.5. Finally, al 10 answers final calculated numbers are summed up to obtain a consolidated SUS scoring ranging from 1 to 100, with an acceptability threshold someone would set at 68 c.a.

In Table 4, consolidated results for COMAU have been shown, comparing the first and second Information and Data Collection Sessions, per each Evaluation Scenario (ES) and per each Evaluation Test (ET).

Table 4 SUS scoring results in COMAU

ES	ET	Who	1st	2nd
1	1	W (1.1)	-	79.2
1	1	DM (1.2)	-	79.2
1	2	W (2.1)	57.1	82.2

1	2	DM (2.2)	63.6	79
2	3	W (3.1)	-	81.5
2	3	DM (3.2)	-	82.2
2	4	W (4.1)	-	80.2
2	4	DM (4.2)	-	80.5
3	6	W (6.1)	65	78.5
3	6	DM (6.2)	64.6	78.2
3	7	W (7.1)	55.5	82.5
3	7	DM (7.2)	55.8	79.8
4	8	W (8.1)	63.2	80.5
4	8	DM (8.2)	63.5	83
5	5	W (5.1)	46.4	79.5
5	5	DM (5.2)	55	81.5
5	9	W (9.1)	69	81
5	9	DM (9.2)	70.4	80

It could be said that the results of the 1st Information and Data Collection Session were "critical", not in the sense they had a critical impact on SatisFactory solutions, but in the sense that they were aimed to constructively criticize the solutions to leverage on improvement points and give a boost to SatisFactory platform growth.

This is fully demonstrated by the dramatic increase of such scores during the 2nd session, that not only encompasses all Evaluation Scenario and Tests (it has been not possible to present the all of them during the previous session), but even reach very positive evaluations. As said multiple times before, room for improvement is always present and denotes a project of success (since user are eager for improvement).

4.1.7.2 Conclusions based on SatisFactory evaluation criteria

So, the first 10 questions of SatisFactory feedback questionnaires have been interpreted accordingly to the SUS Analysis methodology. Other 10 questions were then added to the questionnaire and have instead been used to understand users' opinion on following evaluation criteria:

1) Usability;
2) Knowledge capitalization inside the platform;
3) User experience;
4) Acceptability of the solutions;
5) Impact.

This second step of the evaluation has been performed by calculating the percentage of positive results (i.e. number of people whose rating was > 3 on total number of queried users), percentage of neutral – maybe risk-adverse – users (whose score was exactly $= 3$) and finally percentage of negative marks, i.e. values < 3

The following subchapters will present relevant tables with such data per each Evaluation Scenario and Test, collected both in the 1st and in the 2nd Information and Data Collection Sessions, maybe with some short conclusion.

4.1.7.2.1 Conclusions on Usability

Table 5 Positive feedbacks percentage on Usability criterion in COMAU

ES	Who	1st	2nd
1	W	50	90
1	DM	85.7	45
2	W	-	74
2	DM	-	88.3
3	W	50	90
3	DM	54.2	87.5
4	W	66.64	80
4	DM	78.6	80
5	W	50	100
5	DM	58.3	80

Prior to proceed to the comments regarding the results, a duly description of the Evaluation Tests must be performed. In Table 7, a summary of all nine Evaluation Tests can be found.

To better understand which are SatisFactory tools / exploitable results that have been taken into account per each ET, a further table legenda (see Table 6), have been added, with a recap of all SatisFactory solutions (at least the ones implemented on COMAU premise).

Table 6 SatisFactory exploitable products implemented in COMAU

PARTNER	PLATFORM	TOOL	FEATURES
ISMB	Gesture and Content Recognition Manager	Presence Detection	People count
		Gear Detection	Proactive incident detection
		Hands Free Browsing	Gestures recognition
		Incident Detection	Color camera (Microsoft

			Kinect)
			Depth camera (Microsoft Kinect)
	Multiple Media Manager	Incident Video Recording and Replaying	Ex-post investigation of incidents
		Video Live Streaming	Allows real rime supervision in privacy mode
		Audio Call Management	Emergency audio calls
	Digital Andon	Smart Assembly Station Display	Instructions visualization
			Audio call
		Public Display	APIs for drawing on display
			Notifications panel
	Visualization Toolkit (Web App)	Audio Call	-
		Map View	-
		Incident Replay	-
		Notifications Aggregator	-
		Work Schedule View	-
	Localization Manager	UWB-based localization system	Real-time indoor localization of workers
		Incident detection	Incident detection based on geo-fencing and dynamic generation of forbidden areas
	Ergonomics	Wearable Ergonomics Sensors	Real time monitoring of worker posture
	Intelligent IoT Infrastructure for the Smart Sensor Network (Environmental Sensors)	Single Radio and Multi Radio Sensors	Environmental monitoring and implementation of robust communication techniques
REGOLA	Training Platform	Creation Tool	-
		Presentation Tool	Creation tool on mobile (tablet, smartphone)
			Presentation tool on wearable (GLASSUP F4 smartglasses, Microsoft HoloLens)

			Creation tool on desktop (Microsoft)
		Package2Bundle Tool	-
		Procedure Server	-
	In-Factory Platform	Creation Tool	-
		Presentation Tool	Creation tool on mobile (tablet, smartphone)
			Presentation tool on wearable (GLASSUP F4 smartglasses, Microsoft HoloLens)
			Creation tool on desktop (Microsoft)
		Package2Bundle Tool	-
		Procedure Server	-
FIT	Gamification Framework	Gamification Server	REST API for gamification framework
	Suggestions Platform	Suggestions Frontend	-
	LinkSmart	Event Aggregator	-
		Resources Catalog	-
		Services Catalog	-
CERTH / ITI	Object Recognition System	ORS Server on Linux Supercomputer	-
		ORS Client	-
		High Definition Camera	-
		Depth Camera	-
	Remote Assistance Tool	-	-
	CIDEM	-	-
	Social Collaboration Platform	-	-
GLASSUP	F4 Smartglasses	-	-
ABE	iDSS	Maintenance Toolkit Cloud App	
		ShopFloor Feedback Engine	

		Maintenance Toolkit on-Premise Deployment	
		iDSS	

Table 7 Evaluation Tests summary

ET	DESCRIPTION	CONTENTS (PRODUCTS)	TOOLS
ET1	Assembly operations automation & IIoT	Gesture and Content Recognition Manager	Incident Detection
		Digital Andon	Public Display
		Visualization Toolkit (Web App)	Map View
			Incident Replay
			Notifications Aggregator
			Work Schedule View
		Localization Manager	UWB-based localization system
			Incident detection
		Intelligent IoT Infrastructure for the Smart Sensor Network (Environmental Sensors)	Single Radio and Multi Radio Sensors
		LinkSmart	Event Aggregator
			Resources Catalog
			Services Catalog
		iDSS	ShopFloor Feedback Engine
			iDSS
ET2	Augmented assembly procedures	Gesture and Content Recognition Manager	Presence Detection
			Gear Detection
			Hands Free Browsing
		Multiple Media Manager	Video Live Streaming
			Audio Call Management
		Digital Andon	Smart Assembly Station Display

		Visualization Toolkit (Web App)	Audio Call
			Map View
			Work Schedule View
		Localization Manager	UWB-based localization system
			Incident detection
		Ergonomics	Wearable Ergonomics Sensors
		Training Platform	Creation Tool
			Presentation Tool
			Package2Bundle Tool
			Procedure Server
		In-Factory Platform	Creation Tool
			Presentation Tool
			Package2Bundle Tool
			Procedure Server
		LinkSmart	Event Aggregator
			Resources Catalog
			Services Catalog
		Object Recognition System	ORS Server on Linux Supercomputer
			ORS Client
			High Definition Camera
			Depth Camera
		Social Collaboration Platform	
		F4 Smartglasses	
ET3	Corrective maintenance, HR re-adaptation and workload balancing	Gesture and Content Recognition Manager	Hands Free Browsing
			Incident Detection
		Digital Andon	Public Display
		Visualization Toolkit (Web App)	Map View
			Notifications Aggregator
			Work Schedule View

		Localization Manager	UWB-based localization system
			Incident detection
		In-Factory Platform	Creation Tool
			Presentation Tool
			Package2Bundle Tool
			Procedure Server
		LinkSmart	Event Aggregator
			Resources Catalog
			Services Catalog
		Remote Assistance Tool	
		Social Collaboration Platform	
		F4 Smartglasses	
		iDSS	Maintenance Toolkit Cloud App
			ShopFloor Feedback Engine
			Maintenance Toolkit on-Premise Deployment
			iDSS
ET4	Preventive maintenance, HR re-adaptation and workload balancing	Gesture and Content Recognition Manager	Hands Free Browsing
		Visualization Toolkit (Web App)	Map View
			Work Schedule View
		Localization Manager	UWB-based localization system
			Incident detection
		In-Factory Platform	Creation Tool
			Presentation Tool
			Package2Bundle Tool
			Procedure Server
		LinkSmart	Event Aggregator
			Resources Catalog
			Services Catalog

		Remote Assistance Tool	
		Social Collaboration Platform	
		F4 Smartglasses	
		iDSS	Maintenance Toolkit Cloud App
			ShopFloor Feedback Engine
			Maintenance Toolkit on-Premise Deployment
			iDSS
ET5	Collaboration at ShopFloor level	Digital Andon	Public Display
		Gamification Framework	Gamification Server
		Suggestions Platform	Suggestions Frontend
		Social Collaboration Platform	
ET6	Machine faults recognition and HR risk management	Gesture and Content Recognition Manager	Presence Detection
			Gear Detection
			Incident Detection
		Multipe Media Manager	Incident Video Recording and Replaying
			Video Live Streaming
			Audio Call Management
		Digital Andon	Smart Assembly Station Display
			Public Display
		Visualization Toolkit (Web App)	Audio Call
			Map View
			Incident Replay
			Notifications Aggregator
		Localization Manager	UWB-based localization system
			Incident detection
		Ergonomics	Wearable Ergonomics Sensors

		Intelligent IoT Infrastructure for the Smart Sensor Network (Environmental Sensors)	Single Radio and Multi Radio Sensors
		LinkSmart	Event Aggregator
			Resources Catalog
			Services Catalog
ET7	HR incidents management on the ShopFloor	Gesture and Content Recognition Manager	Presence Detection
			Gear Detection
			Incident Detection
		Multipe Media Manager	Incident Video Recording and Replaying
			Video Live Streaming
			Audio Call Management
		Digital Andon	Smart Assembly Station Display
			Public Display
		Visualization Toolkit (Web App)	Audio Call
			Map View
			Incident Replay
			Notifications Aggregator
		Localization Manager	UWB-based localization system
			Incident detection
		Ergonomics	Wearable Ergonomics Sensors
		Intelligent IoT Infrastructure for the Smart Sensor Network (Environmental Sensors)	Single Radio and Multi Radio Sensors
		LinkSmart	Event Aggregator
			Resources Catalog
			Services Catalog
ET8	On the job training	Gesture and Content Recognition Manager	Hands Free Browsing

		Digital Andon	Smart Assembly Station Display
		Training Platform	Creation Tool
			Presentation Tool
			Package2Bundle Tool
			Procedure Server
		LinkSmart	Event Aggregator
			Resources Catalog
			Services Catalog
		Object Recognition System	ORS Server on Linux Supercomputer
			ORS Client
			High Definition Camera
			Depth Camera
		Social Collaboration Platform	
		F4 Smartglasses	
ET9	Gamification in ShopFloor working environment	Digital Andon	Public Display
		Gamification Framework	Gamification Server
		Suggestions Platform	Suggestions Frontend
		Social Collaboration Platform	

Following comments would be structured accordingly to the evaluation scenario and encompass both general considerations that would comprehend all 5 evaluation criteria (usability, knowledge capitalization, user experience, acceptability and impact) plus usability-specific conclusions.

ET1) Assembly operations automation & IIoT

The overall results are a bit poor on this item. This is mainly due to the fact that Iot and IIoT are not main SatisFactory focuses and furthermore on the fact that interviewed people (whether they were “SatisFactory champions”, i.e. workers that always participated to project activities, or newcomers) would probably have preferred to see a more robust integration of IoT data, both human-centered ones and machine signals, respectively into adaptive WorkPlaces and maintenance procedures (triggering interventions, generating dynamic scheduling of maintenance resources, changing the execution flows as per what happens with fault & diagnosis trees, …).

ET2) Augmented assembly procedures

Augmented procedures generation, management, sharing and visualization, supported on heterogeneous, innovative platforms and enriched by multimedia – especially VR and AR – are definitely SatisFactory most impacting findings!

Workers' results (ET1.1) are definitely good, nevertheless they are a bit affected by senior workers, whose learning curves are slower with respect to young, digital native generations, used to exploit mobile and wearable devices in their everyday life and user experience (consumerization of business applications). Furthermore, smartglasses encounter always some concerns when applied into industrial environments, since they dramatically change the way people are working and furthermore can at first generate some small diseases in not used people, especially whether worn for long periods of time. Nevertheless, AR and smartglasses could not avoid to generate "wow-effects" and to captivate people.

Another thought on the 74% score (i.e. 74% of Line Operators considered population retuning a positive feedback) is that tablets (used for the demonstrations) are per se not wearable, thus not leaving hand free during manufacturing or other assembly operations; they are less "usable" in this sense.

For what concerns Decision Makers, considering their scores are always "less enthusiastic" with respect to Workers' – due to the fact that they positively criticize every new application, just to let it grow and rescue the higher success possible – the outstanding result of 88% – something (see Table 5 fairly above) means that they have really been stunned by a platform thought for them, i.e. he Creation Tool; REGOLA Creation Tool is indeed one of the first environments (SDKs), though to let people with no knowledge of programming, 3D modeling, … to create applications and digital procedures, enriched with VR and AR contents, through block and visual programming paradigms.

Albeit this achievement, further improvements would be made on their opinion, like rendering in a simple way the platform (adding for example 3D environment plugins), bringing the Procedure Server on Cloud for a better sharing of material, making of the Creation Tool a SaaS (Software as a Service) tool, allowing for concurrent access and modification of procedures, making of SatisFactory suite a PaaS (Platform as a Service) itself, …

ET3) Corrective maintenance, HR re-adaptation and workload balancing

ET4) Preventive maintenance, HR re-adaptation and workload balancing

ET3 and ET4 are analyzed altogether, since they both are focused on maintenance activities scheduling (in real time, based on machine events or conditions, cross-checked with periodic, programmed and autonomous maintenance calendars, MTBF data, …) and execution through augmented procedures. Last but not least the stunning remote maintenance assistance and support tool developed by CERTH / ITI and integrated into REGOLA Presentation Tool.

The results clearly highlight COMAU high interest toward maintenance activities, both on Decision Maker side – trying to improve actual documentation (manuals and calendars) generation and hardcopies proliferation, and on Workers, i.e. Service Engineers, behalf, dramatically improving the actual way they are working: responding to emergency calls h24 worsened by information asymmetry with people

on field, having to rashly intervene on-site to perform interventions, having to deal with non-interactive hardcopies of sometimes not updated documentation, …

ET5) Collaboration at ShopFloor level

Manufacturing and HR resources that participated to questionnaire filling but also to other project steps, demonstrated a very high interest toward gamification initiatives, since they represent a very new trend in industrial environment, but move factories of the future toward a Google-like organization, where people creativity and contribution is empowered by gamification initiatives indeed.

ET6) Machine faults recognition and HR risk management

Good results here are motivated by a growing attention paid in Industries 4.0 to adaptive WorkPlaces.

4.1.7.2.2 Conclusions on Knowledge Capitalization

Table 8 Positive feedbacks percentage on Knowledge Capitalization criterion in COMAU

ES	Who	1st	2nd
1	W	33.3	63.3
1	DM	66.7	43.3
2	W	-	47.5
2	DM	-	96.7
3	W	66.7	96.7
3	DM	83.3	83.3
4	W	75	75
4	DM	60.7	85
5	W	37.5	83.3
5	DM	61.1	90

ET1) Assembly operations automation & IIoT

The potentials of knowledge capitalization of IoT, IIoT and analytics systems (Machine Learning and Artificial Intelligence included) are impressive, but not 100% exploited by SatisFactory since, again, this is not the main focus of the project.

ET2) Augmented assembly procedures

For System Engineers of After Sales Technical Service experts (belonging to the Decision Makers cluster), the possibility of having a common, share repository were stocking already generated assembly or maintenance procedures for reuse, is unevaluable.

For Workers, maybe some more efforts should have been devoted to Lessons Learned capitalization from the ShopFloor integration in these tools.

ET3) Corrective maintenance, HR re-adaptation and workload balancing

ET4) Preventive maintenance, HR re-adaptation and workload balancing

Same considerations than for ET2; in this case although, since people performing maintenance interventions (i.e. Service Engineers), overlaps lot of times with resources devoted to procedures generation, the Workers' score is higher.

ET5) Collaboration at ShopFloor level

Gamification and collaboration do encompass HR involvement and team building implicit knowledge and skills; furthermore FIT Suggestion Platform is dramatically valuable for capitalizing Lessons Learned from the ShopFloor, giving satisfaction to Workers and assuming a critical relevance for Decision Makers working inside a World Class Manufacturing[3] (WCM) compliant company.

---

[3] World Class Manufacturing can be defined as a complete methodology prescribing rigorous approaches and tools implementation in order to dramatically and continuously improve organizational cultures not only in industrial companies, but in every organization – from personal life and domestic economy to services (e.g. one of WCM implementation benchmarks is the UK Royal Mail brilliant case study).

Accordingly to the methodology itself historical heritage, two souls live inside World Class Manufacturing body, thanks also to main contributors of its corpus of knowledge and theorists. The first stream follows operational excellence principles, aimed to strategically position companies suffering the strains of cost competition in a saturated market, where an excess in Offer requires for price demolition to cheer Demand up. Market diversification and outclassing competitiveness may be achieved with in-process quality aimed to tackle waste and losses (in time, cost and scope, where even occupied space wears the garments of cost) with problem solving competences, increasing production efficiency on one side, and delivering outstanding excellence to customer accordingly to zero errors and zero defects criteria (vertical differentiation).

This line sinks its roots into Total Quality Management (TQM) model, born in Japan during the Fifties and into the Lean Production crusade against disposals (the struggle against contributions not meant to add value to the product, whether physical or not) in Toyota pull system. Anyway such inseparable spirit of the WCM is probability not the one that deserves more interest inside SatisFactory project. The Human part of the methodology is mainly due to the work of Dr. Schonberger, theorist of the professional development of workers through making Them responsible and involving Them, as key factor for working conditions change and strategic positioning of companies.

World Class Manufacturing proposes substantially a holistic approach, where all people of the organization should be involved into the continuous improvement and contribute to the development, increase, capitalization and maintenance of company know-how.

This attention paid to people can be found multiple times inside World Class manufacturing theoretical infrastructure. WCM methodology is, briefly, based on ten managerial pillars building the base on top of which again ten technical pillars sustain WCM temple tympanum. For example, the central role of human capital can be found in first technical pillar, i.e. "Safety" (SA): one company is made of people; therefore it should struggle to ensure zero incidents. Again Human Resources centered approach returns into Autonomous Activities (AA) technical pillar aiming to continuously improve working environment, restoring basic (as-is) conditions, enhancing ergonomics on the WorkPlace (stuff indeed for "WorkPlace Organization" – WO sub-pillar of AA technical pillar) and making workers first responsible for the maintenance and standardization of their working positions (machines or whatsoever), with "Autonomous Maintenance" (AM) subpillar. Probably maximum exemplum of

ET6) Machine faults recognition and HR risk management

Supervision and monitoring activities, previously relieving upon supervisors and Ergonomics Engineers responsibility and left to their expert judgment, are now dramatically improved by adaptable WorkPlaces and decision support tools developed by SatisFactory.

4.1.7.2.3 Conclusions on User Experience

Table 9 Positive feedbacks percentage on User Experience criterion in COMAU

ES	Who	1st	2nd
1	W	58.3	80
1	DM	57.1	45
2	W	-	45
2	DM	-	90
3	W	65	56.7
3	DM	66.7	100
4	W	62.5	82.5
4	DM	92.9	90
5	W	58.3	100
5	DM	33.3	100

ET1) Assembly operations automation & IIoT

Here, the scores are prizing and awarding again the attention paid by SatisFactory project toward humans, trying to bring IoT and IIoT more and more from machines toward people (ISMB Ergonomics Sensors, Localization Tags, …).

ET2) Augmented assembly procedures

---

people-centered design of WCM revolution of factory organization is anyway the “People Development” technical pillar.

On managerial pillar side instead, the whole structure is devoted to people; a change in management, communication, dissemination and awareness, common vision and intents, training and motivation, capitalization of lessons learned, planning and scheduling are of crucial importance to make possible the technical path to spread inside the company.

Thanks to “Cost Deployment” technical pillar (CD), Benefit on Cost Ratio (B/C) is another way – maybe simpler but even more metaphoric – to calculate ROI (Return on Investment), not considering money gained times spent, but money that have not been wasted against money spent to avoid this disposal.

On ET2 COMAU considerations are very similar to the ones expressed under usability criterion; user experience and usability are indeed very similar, even if – maybe – the first is more related to technical feasibility of implementation on a ShopFloor.

Anyway, Workers' learning curves and technology adoption trends (till in the Innovators / Early Adopters phase, see Figure 37) affect a bit their feedback; block and visual programming instead maximize procedures creators' user experience.

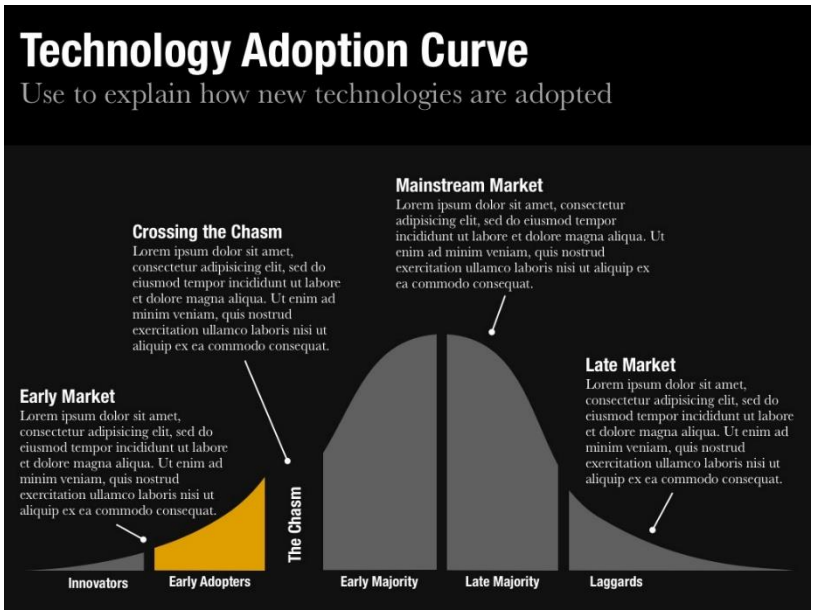


Figure 37 Technology adoption curves

ET3) Corrective maintenance, HR re-adaptation and workload balancing

ET4) Preventive maintenance, HR re-adaptation and workload balancing

On maintenance topics, maintenance procedures creators are definitely benefitted and their user experience is really good. On operative side, Service Engineers eager for improvement of maintenance calendars and reactive maintenance activities triggering, based on real time machine signals integration, maintenance resources skills profiling, maintenance technicians workloads balancing, resources positioning inside the ShopFloor (ask for intervention to the nearest technician without higher priority tasks and with skills needed to solve the specific issue), …

ET5) Collaboration at ShopFloor level

Involved resources have proven to be enthusiast toward an initiative that represent a novelty promising to valorize workers and empower their contribution to overall factory and company wellness.

ET6) Machine faults recognition and HR risk management

Tools presented in ET6 encountered an high favor under user experience perspective since they definitely help people, both Workers and Supervisors, to feel safer on the ShopFloor.

4.1.7.2.4 Conclusions on Acceptability

Table 10 Positive feedbacks percentage on Acceptability criterion in COMAU

ES	Who	1st	2nd
1	W	75	80
1	DM	64.3	45
2	W	-	87.5
2	DM	-	80
3	W	36.7	86.7
3	DM	45.8	92.5
4	W	83.3	80
4	DM	85.7	70
5	W	61.9	61.9
5	DM	73.3	90

ET1) Assembly operations automation & IIoT

The human IoT / IIoT solution suffers of some drawbacks regarding the acceptability due to privacy concerns; monitoring of workers position (localization), of workers current activities, of workers skills, video surveillance and – especially – monitoring of anthropometric parameters, could be perceived as measurement of human performance or as an inappropriate, undue and undeserved intrusion into sensitive data.

Similar considerations could be performed on ET6 – Machine faults recognition and HR risk management.

ET2) Augmented assembly procedures

Again, even under acceptability criterion and perspective, the attractiveness and captivation of new technologies, AR and wearable devices, fight against learning and adoption curves. Very positive instead the feedback on the simplification of procedures generation, making things simple for resources without programming skills and even for non-digital natives, thanks to REGOLA Creation Tool development environment.

ET3) Corrective maintenance, HR re-adaptation and workload balancing

ET4) Preventive maintenance, HR re-adaptation and workload balancing

Maintenance support would receive a dramatic boost from people dealing with on-field interventions and “call-center” support; nevertheless for what concerns remote maintenance support / assembly, on the technical side, network performance

reliability should still be accepted by many people plus possibility of drawing instructions on a video stream to be shown in AR on field should still be implemented; on relationship side, many people would instead continue to require for face to face, on field intervention.

Furthermore, since maintenance technicians allocation to an intervention based on distance of the person from accident place is possible only with localization solutions, again some privacy concerns would arise.

ET5) Collaboration at ShopFloor level

Newness is always attracting; nevertheless, Workers would still suffer some shyness on non-anonymous contributions and suggestions.

ET6) Machine faults recognition and HR risk management

Please refer to the privacy matter expressed on ET1.

4.1.7.2.5 Conclusions on Impact

Table 11 Positive feedbacks percentage on Impact criterion in COMAU

ES	Who	1st	2nd
1	W	83.3	80
1	DM	85.7	0
2	W	-	48
2	DM	-	82
3	W	60	95
3	DM	50.8	81.2
4	W	75	70
4	DM	57.1	90
5	W	83.3	91.7
5	DM	69.1	92.9

For impact criterion, no further division into paragraphs addressing each single Evaluation Test would be needed. SatisFactory tools came from the ShopFloor (accordingly to Design Thinking, simultaneous engineering and Agile Project Management methodologies) and would have a definitely impressive impact on it.

Just a few comments. IoT and IIoT are the future for manufacturing; in order SatisFactory solutions in this field to be impacting and skyscraping, some work still needs to be done.

Instead, AR solutions urge to be brought in the ShopFloor widely: only people touching it with hands would be able to recognize how impressively this solutions would enhance their everyday working life and user experience!

4.1.7.3 Feedback on exploitable products

Several have been the opportunities to share altogether with SatisFactory technical partners users opinions and suggestions on developed and tested tools.

As stated above, feedback have always been positive or – if not – at least critical for the good evolution of the project. A very valuable system developed in order to collect at least part of these outcomes, is a Willingness to Have (WTH) questionnaire, distributed by GLASSUP and, later on, modified by QPLAN / COMAU and delivered even to all the attendants to SatisFactory Final Workshop, held in COMAU – Grugliasco on Friday December, 15th 2017.

The valuable results of such questionnaires are briefly summarized here.

SatisFactory mainly consists of three streamlines, i.e. SatisFactory exploitable products can be grouped in 3 major clusters:

1) **Im DSS**
   This first cluster comprises iDSS platform and all tools devoted to incident detection and management, especially the ones related to machines / equipment and/or coming from a smart sensors IoT (IIoT).

2) **STUuDIOUS**
   STUuDIOUS platform groups instead all tools and features addressing the problems of monitoring and supervision inside the ShopFloor, included – but not limited to – indoor localization problem.

3) **Fractar (Framework for Creative Tools of Augmented Reality)**
   The suite collecting all tools and development environments (SDK) needed to create digital assembly or maintenance procedures, to enrich them with multimedia and especially VR / AR features and to visualize them in the ShopFloor through innovative and captivating mobile or wearable HMIs (from smartphone and tablets to smartglasses).

Albeit the all three are implemented on COMAU premises, the ones COMAU had the opportunity to test and experience more are STUuDIOUS and Fractar; thus, following conclusions would deal more with the two of them. Furthermore, since the involved actors range from System Engineers to Manufacturing and Technical Leaders, from Process Operators to After Sales Service Engineer, the comments would encompass several capital COMAU departments: production, service, engineering and innovation.

SatisFactory tested tools and bundles – especially Fractar – represent really an outstanding result in providing companies with an open development environment to create their own applications with a very intuitive, user friendly drag & drop and block programming like paradigm.

Thou some more efforts should be done in the future on integration of new features (e.g. 3D modelling environment plugin), compatibility with industrial legacies and formats, plus supplementary simplification and boosting of users independence in tools full exploitation.

Anyway, it has to be underlined that the presence of a so high number of improvement points is really an outstanding success of SatisFactory platform, since it shows the relevance, impact and interest it deserved in industrial environments!
Now, a few words on each component and service related to SatisFactory platform.

1) **Hardware**
   The provided hardware is sometimes “quick and dirty” that is definitely a strength of the project since it has a very low latency and allows for very high responsiveness, but lacks of final industrialization of the solutions themselves.
2) **Software**
   Please refer to what stated briefly above on the power, potentials and impact of drag & drop and block programming.
3) **Support**
   The support received from some partners has definitely a very high QoS (Quality of Service)! Availability and competence characterize some technicians and experts of such partners. With some other partners collaboration has been a bit more tricky, probably even due to geographical distance, but availability has never been an issue! Maybe, when SatisFactory platform would consolidate in a sellable product, the geographic support network should be addressed as an opportunity and enforced.
4) **Integration**
   Integration among SatisFactory solutions and between SatisFactory platform and company legacies or other systems should be definitely improved.
   A key success factor would be enable integration also for end users, creating easy to use APIs and interfaces and providing ontologies and semantics engines (toward an integrated IIoT – Industrial Internet of Things).

Regarding overall evaluation of SatisFactory project period, it has proven to be really successful and with multiple outstanding results. Instead of technical achievements, a duly consideration should be made on “satisfaction” achievements. The best results has been having COMAU people asking for a rapid dissemination of the solution on the entire ShopFloor, included but not limited to COMAU Manufacturing management. Furthermore, as stated multiple times above, the fact that lot of improvement suggestions have come out during the project lifecycle, means that the solution is really of major interest for the Company.

No major issue has instead occurred during the project execution and testing phase, thanks to the good management capabilities of industrial and coordinating partners and thanks to the high availability and skills of technical ones. Nevertheless, one lessons learned that should be earned by this experience is never to disappoint users expectations, in order not to lose project boost and contributing stakeholders commitment.

Furthermore, the very good cooperation among partners can be even increased, in order to proceed to a more smooth and gradual integration of developed tools, maybe – compatibly with geographical issues – proceeding per periodic increments (Scrum Cycles) with continuous, real time feedback, accordingly to Agile methodologies.

Following subchapters would instead focus a bit more on conclusions on single SatisFactory exploitable products (bundles). The evaluations have been performed accordingly to five main criteria:

1) Improving safety

2) Improving quality
3) Saving time
4) Improving collaboration
5) Improving maintenance
6) Improving processes workflow

4.1.7.3.1 Im DSS Bundle

Safety first. Even if incident detection is a reactive tool and cannot – by so – prevent accidents, surely it improves a lot the capability of recognizing one incident and take efficiently, effective countermeasure (increases awareness and responsiveness).

Maintenance will benefit a lot both from incident detection (automatic forbidden areas generation from ISMB), again improving awareness of breakdowns and reactiveness of interventions, and from ABE applications, allowing for an agile scheduling and rescheduling of pre-emptive (periodic) maintenance interventions. The integration of both tools would instead allow, in case of a breakdown, for fast allocation of right maintenance staff / skills, based on current resources scheduling, competences mapping, priorities management and work for discontinuities plus – why not –localization of people in the ShopFloor (with respect to accident place).

Saving Time is crucial for maintenance intervention, and even – especially – for support intervention in case of accidents involving people. Saving time can mean both saving lives and saving money.

Choosing the right person that should intervene in case of breakdown, is crucial for intervention effectiveness, to avoid reworks or further problems and to avoid the need of involvement of senior, more skilled resources. In this sense Im DSS tackles **quality**.

But, to achieve this collaborative, dynamic scheduling, **collaboration** is needed, in the sense of collaborative HR management.

If **workflow** is meant as scheduling, it should be integrated into the concept of collaboration; otherwise, if it refers to the procedural management of ShopFloor processes, Im DSS is not meant to for this purpose.

4.1.7.3.2 STUDdIOUS Bundle

The ranking is very similar to the one assessed for Im DSS suite, since the localization part is considered mainly integrated with incident and maintenance intervention management.

The only difference is the **workflow improvement** relevance rising up inside the ranking, since the middleware, meant as IoT (IIoT) middleware, gives and impressive boost into procedures management, execution and monitoring on the ShopFloor.

4.1.7.3.3 Fractar Bundle

Procedure creation, management, sharing and visualization on the ShopFloor dramatically improve **processes workflow**.

Even **maintenance** procedures execution benefits in the same way of Fractar platform.

Step by step guided, multimedia, VR and AR enriched and error-proof procedures, lead to cycle **time reduction** and **quality improvement** (avoid scraps / reworks).

Fractar can be considered **collaborative** under two aspects: the stunning possibility of requiring for remote support (enriched by video streaming and real time AR visualization – i.e. the remote technician can draw on the screen while the on field worker can see instructions in AR) plus collaborative sharing of operational know-how on the ShopFloor, from senior, highly skilled employees, to new hired or relocated people (increasing job flexibility, smoothing learning curves steepness).

Safety first; but in this case, safety is only marginally implied. I.e. guided procedures execution can prevent errors that can lead to harmful conditions or accidents.

4.2 EVALUATION RESULTS AT SUNLIGHT

Just like with COMAU, two data collections were carried out at SUNLIGHT as well, for which we present detailed charts below. To improve readability and to avoid interpreting each chart separately, we will comment only on the comparison between the two measurements and not on each measurement alone. After all, the progress due to the project is important, while each single value by itself is meaningless. We will comment each specific measurement only where it is necessary or to highlight important points. The age, experience, and years of employment data are presented as charts for information purposes only. The distribution of these characteristics among participants is similar to the real distribution in the workforce at SUNLIGHT, therefore no special remarks need to be done on each chart separately.

The number of responses at SUNLIGHT is sufficient to generalize the SUS questionnaire results. While a margin of error still exists, it is not so large as to cast doubt on the observed trends.

4.2.1 Evaluation Scenario 1 Results

It is reminded that the Evaluation Scenario 1 (Supporting Assembly Operations), is comprised by two scenarios (ES1.1: Automated support for assembly operations and ES1.2 AR supported assembly operations). The data collection is done using two questionnaires (ET1 Automated Support for Assembly Operations and ET2 AR Supported Assembly Operations).

4.2.1.1 ES1 Workers' Results

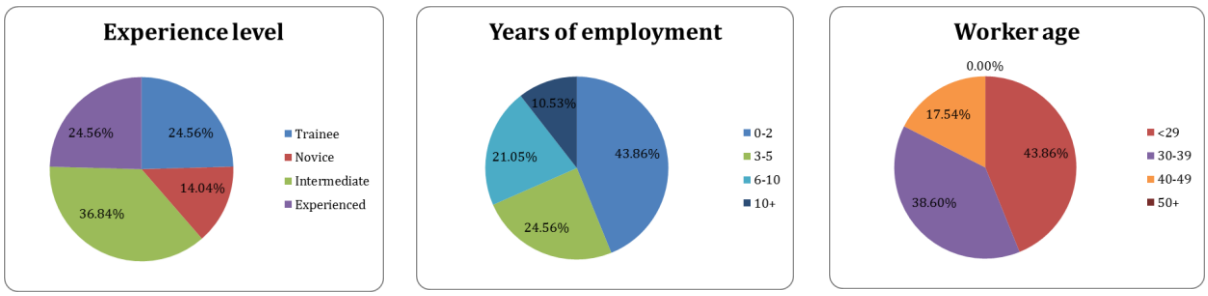
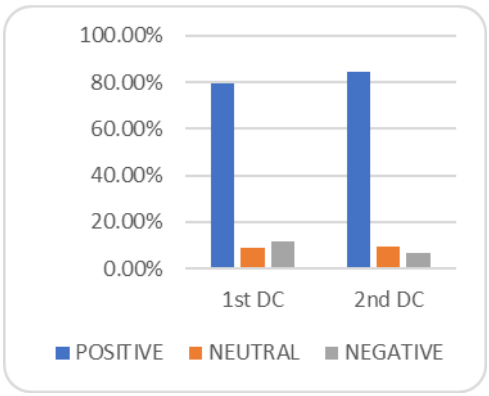
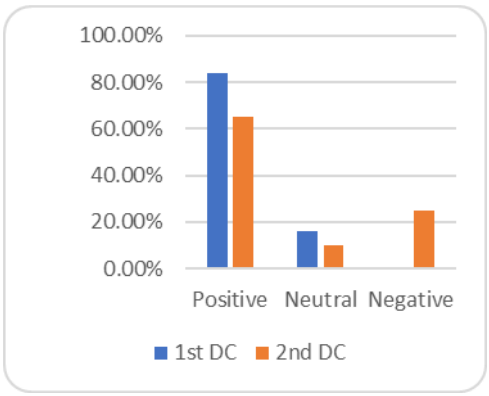


Figure 38 ES1 Workers, Sunlight

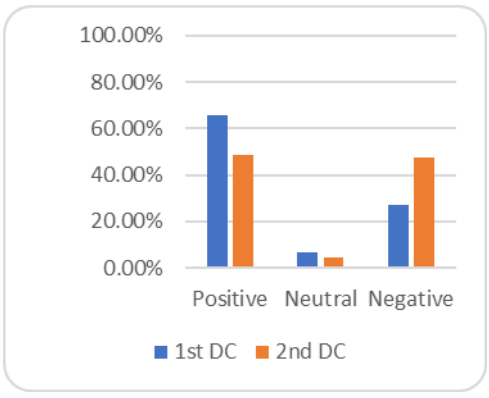
During the 1st Data Collection period at Sunlight 11 workers responded for ET1.1 and 11 workers responded to ET2.1, while in the 2nd Data Collection period 18 workers responded to ET1.1 and 17 workers responded to ET2.1.



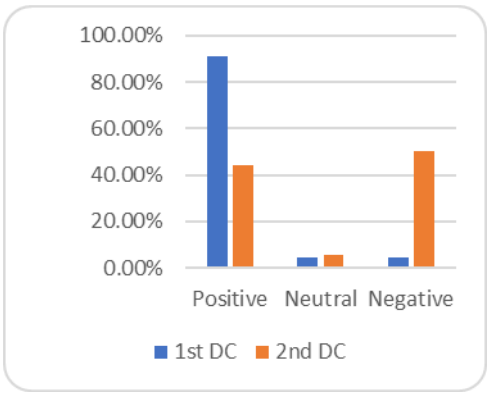
(a) General Evaluation



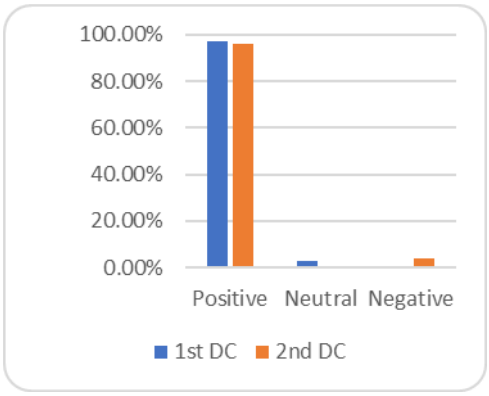
(b) Usability



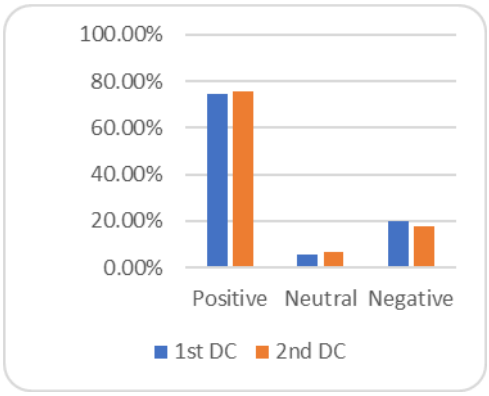
(c) Knowledge Integration



(d) Working Experience



(e) User Acceptance

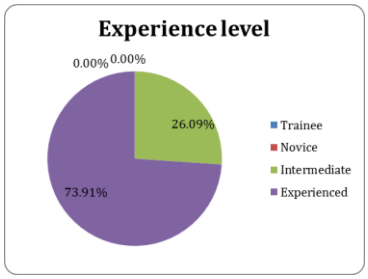


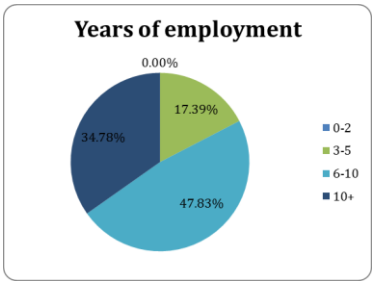
(f) Overall Impact

Figure 39 ES1-Workers, SUNLIGHT: Supporting Assembly Operations

There is a noticeable drop in the overall score in several metrics for the second evaluation. The overall evaluation is positive, but we may not exclude a Hawthorne effect here. The single metrics at first sight seem to hint at a negative effect of the Satisfactory approach in ES1, however, as explained in section 4.2.7, this may be due to the "in progress" nature of the Satisfactory implementation, which did not allow responders to experience the complete system uninterrupted by upgrades and improvements.

4.2.1.2 ES1 Decision Makers' Results





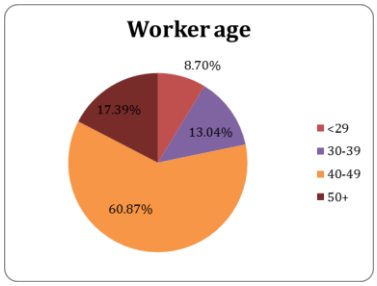
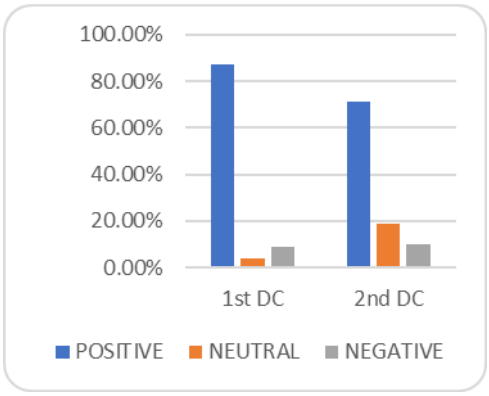
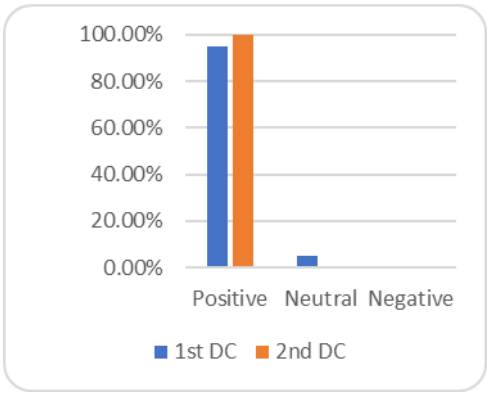


Figure 40 ES1 Decision Makers, Sunlight

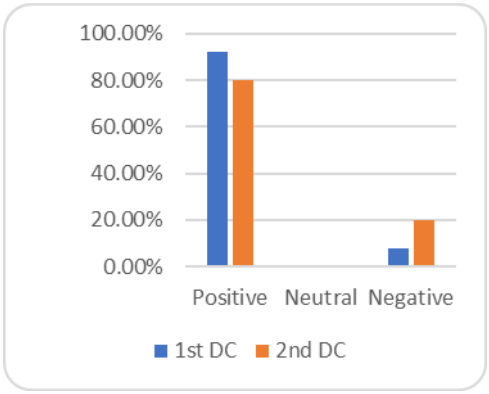
During the 1st Data Collection period at Sunlight 5 decision makers responded for ET1.2 and 5 decision makers responded to ET2.2, while in the 2nd Data Collection period 7 decision makers responded to ET1.2 and 6 decision makers responded to ET2.2.



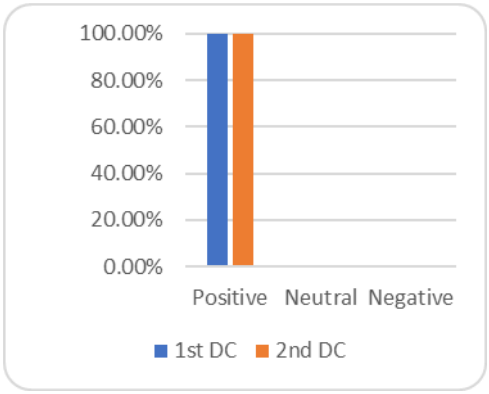
(a) General Evaluation



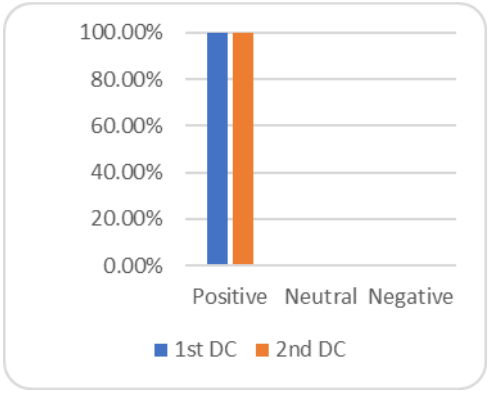
(b) Usability



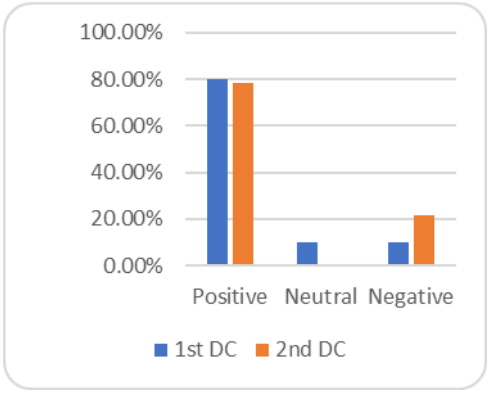
(c) Knowledge Integration



(d) Working Experience



(e) User Acceptance



(f) Overall Impact

Figure 41 ES1-Decision Makers, SUNLIGHT: Supporting Assembly Operations

Unlike with the COMAU evaluation, where decision makers typically had higher satisfaction scores than workers, the SUNLIGHT pilots see a lower score from decision makers. The

reasons may need to be investigated, but the discrepancy may result from there being less focus on manager-specific tasks in the SUNLIGHT pilot.

4.2.2 Evaluation Scenario 2 Results

The Evaluation Scenario 2 (Offering Maintenance, Re-adaptation & HR Workload Balancing Services) is comprised of two scenarios (ES2.1 Corrective Maintenance, Re-adaptation & HR Workload Balancing and ES2.2 Preventive Maintenance, Re-adaptation & HR Workload Balancing). The data collection is done using two questionnaires (ET3 Corrective Maintenance, Re-Adaptation & HR Workload Balancing and ET4 Preventive Maintenance, Re-Adaptation & HR Workload Balancing).

4.2.2.1 ES2 Workers' Results

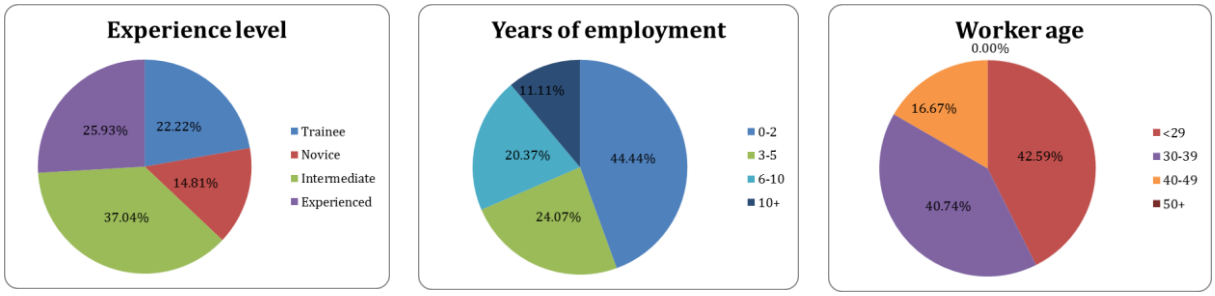
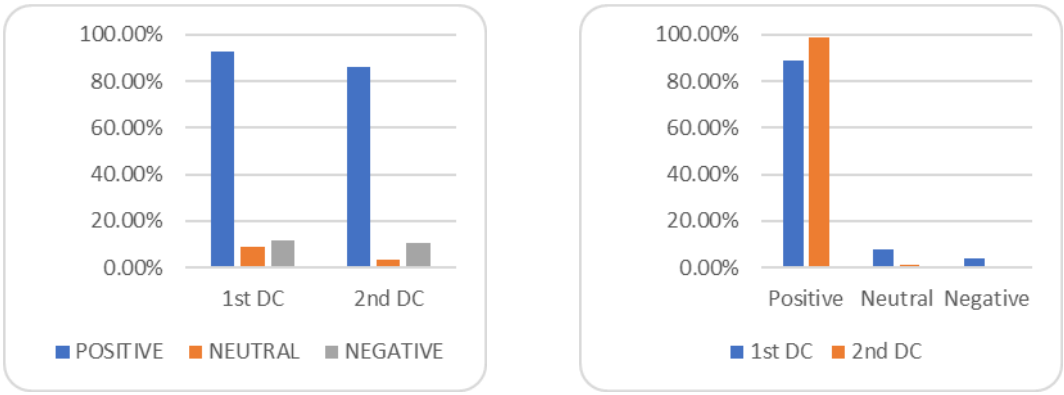


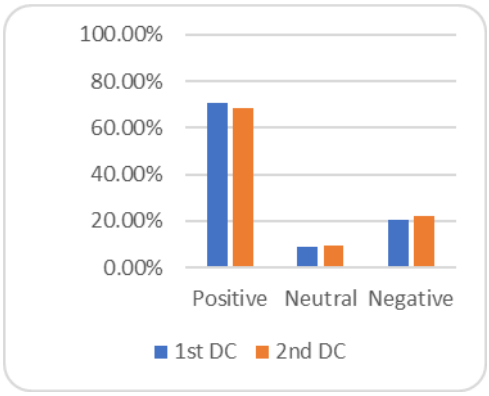
Figure 42 ES2 Workers, Sunlight

During the 1st Data Collection period at SUNLIGHT 11 workers responded for ET3.1 and 6 workers responded for ET4.1, while in the 2nd Data Collection period 17 workers responded to ET3.1 and 16 workers responded to ET4.1.

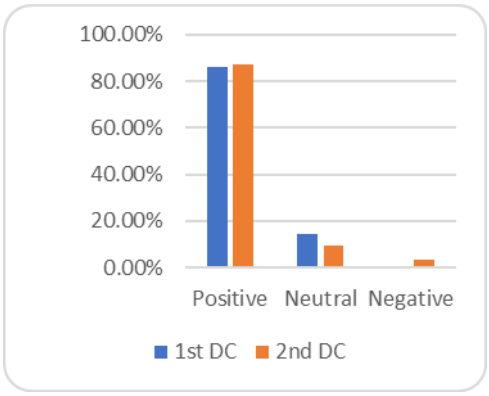


(a) General Evaluation

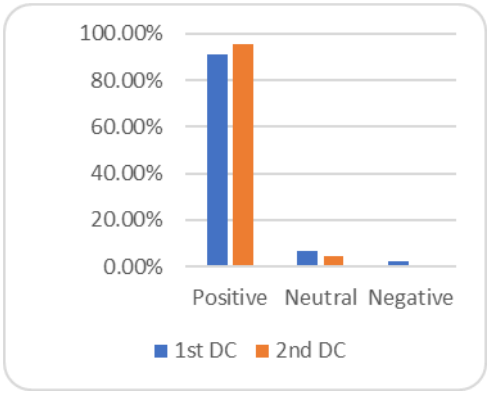
(b) Usability



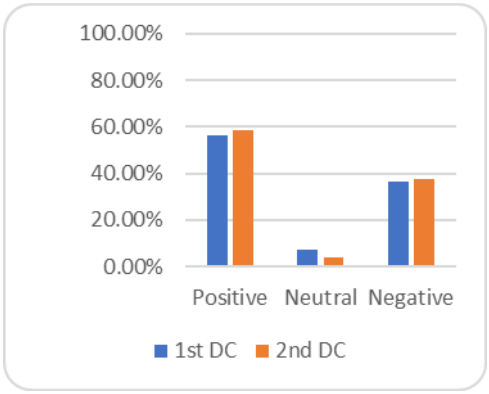
(c) Knowledge Integration



(d) Working Experience



(e) User Acceptance



(f) Overall Impact

Figure 43 ES2-Workers, SUNLIGHT: Offering Maintenance, Re-adaptation & HR Workload Balancing Services

The comparison for ES2 at SUNLIGHT is positive: the second data collection confirms improvement on the general evaluation and in almost all metrics except knowledge integration. Even here, the difference is too small and within the margin of error. It is particularly positive that the usability, acceptance, and experience scores have increased, though they were high to start with.

4.2.2.2 ES2 Decision Makers' Results

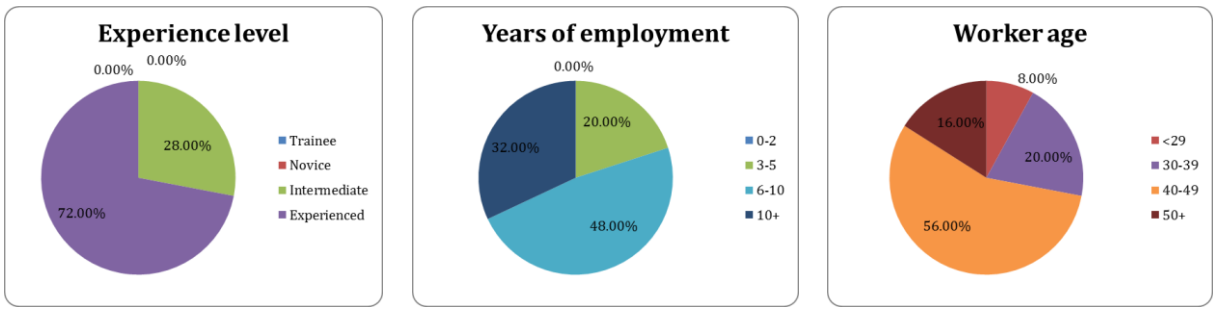
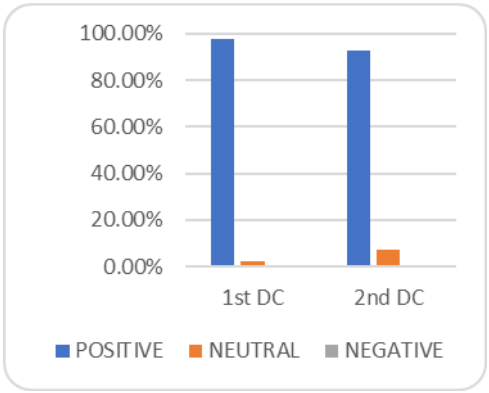
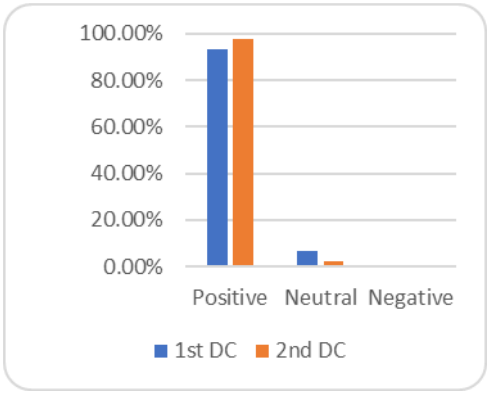


Figure 44 ES2 Decision Makers, Sunlight

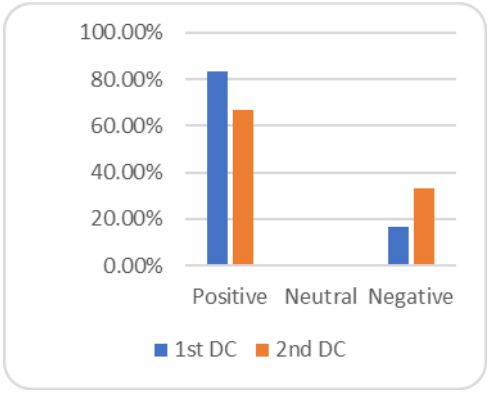
During the 1st Data Collection period at SUNLIGHT 5 decision makers responded for ET3.2 and 6 decision makers responded for ET4.2, while in the 2nd Data Collection period 7 decision makers responded to ET3.2 and 7 decision makers responded to ET4.2.



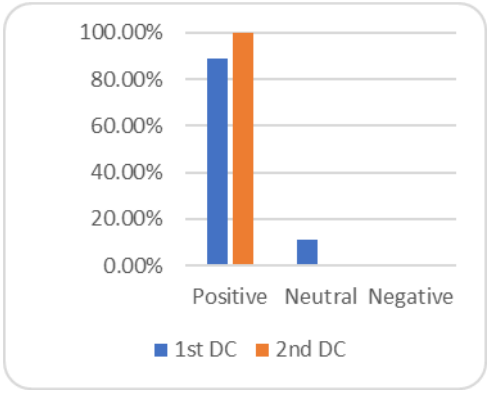
(a) General Evaluation



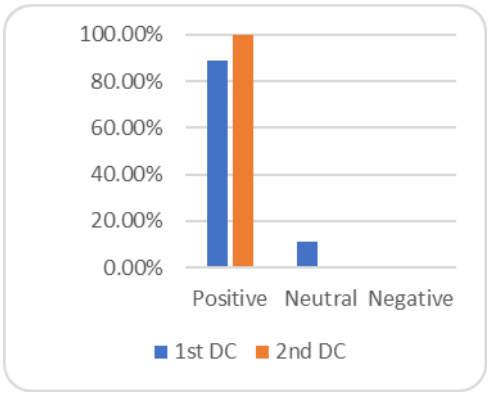
(b) Usability



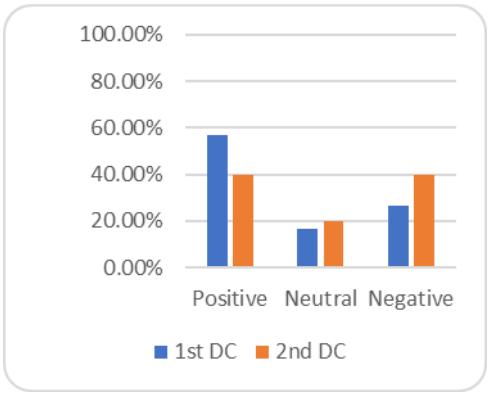
(c) Knowledge Integration



(d) Working Experience



(e) User Acceptance



(f) Overall Impact

Figure 45 ES2-Decision Makers, SUNLIGHT: Offering Maintenance, Re-adaptation & HR Workload Balancing Services

The comparison of the ES2 evaluation results for decision makers continues the trend as ES1: while the scores are highly positive, the second data collection is having a lower evaluation than the first one. As we previously reported, this may need to be investigated deeper. The results may also point to insufficient communication and expectation management among decision makers i.e. perhaps they expected more functionality geared to them as opposed to a sharp focus on the workers.

4.2.3 Evaluation Scenario 3 Results

It is reminded that the Evaluation Scenario 3 (Supporting Incident Detection & Recognition Operations), is comprised by two scenarios (ES3.1: Supporting recognition of incidents in equipment/operations and ES3.2 Recognizing Incidents with Humans on the Shop-Floor). The data collection is done using two questionnaires (ET6 Recognition of incidents in equipment/operations and ET7 Recognition of incidents with humans on the shop-floor).

4.2.3.1 ES3 Workers' Results

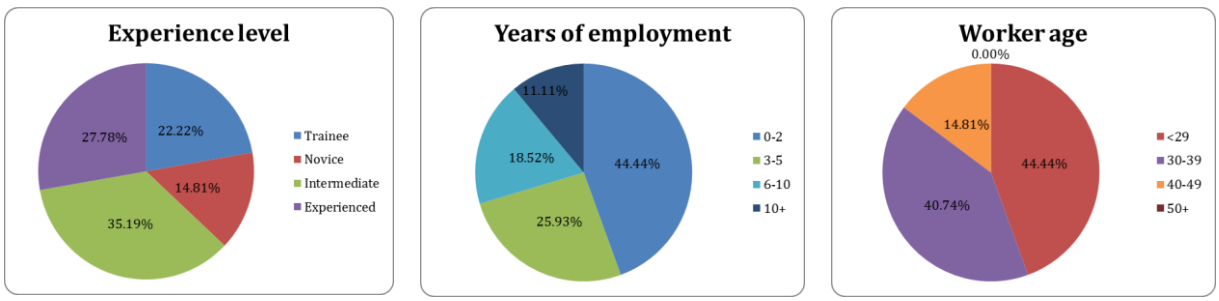
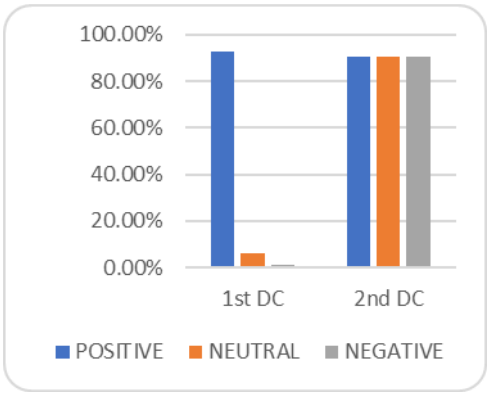
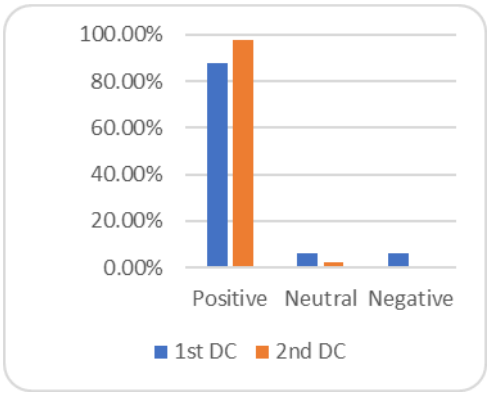


Figure 46 ES3 Workers, Sunlight

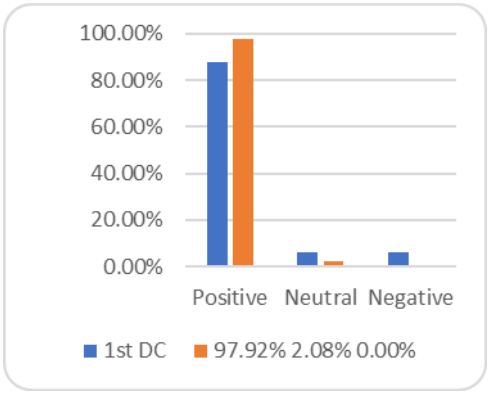
During the 1st Data Collection period at SUNLIGHT 11 workers responded for ET6.1 and 11 workers responded to ET7.1, while in the 2nd Data Collection period 16 workers responded to ET6.1 and 16 workers responded to ET7.1.



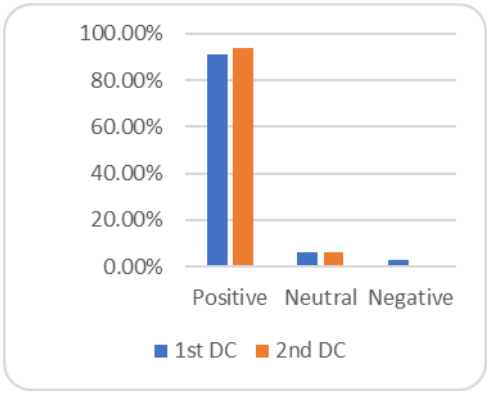
(a) General Evaluation



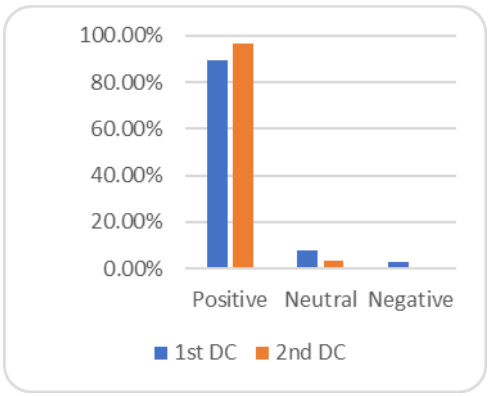
(b) Usability



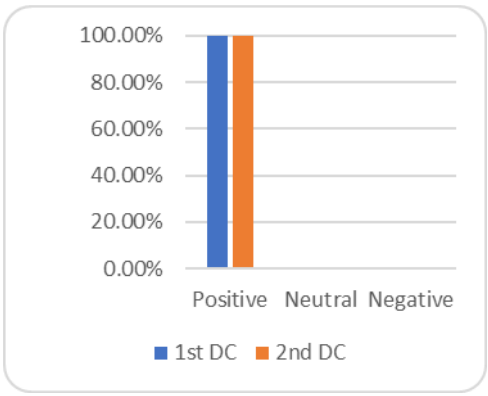
(c) Knowledge Integration



(d) Working Experience



(e) User Acceptance



(f) Overall Impact

Figure 47 ES3-Workers, SUNLIGHT: Supporting Incident Detection & Recognition Operations

ES3 evaluation is in line with the previous two scenarios. The workers' evaluation increases in the second measurement, as expected. Of particular note is the fact that all metrics increase this time, as opposed to the previous scenarios where one metric typically slightly decreased.

4.2.3.2 ES3 Decision Makers' Results

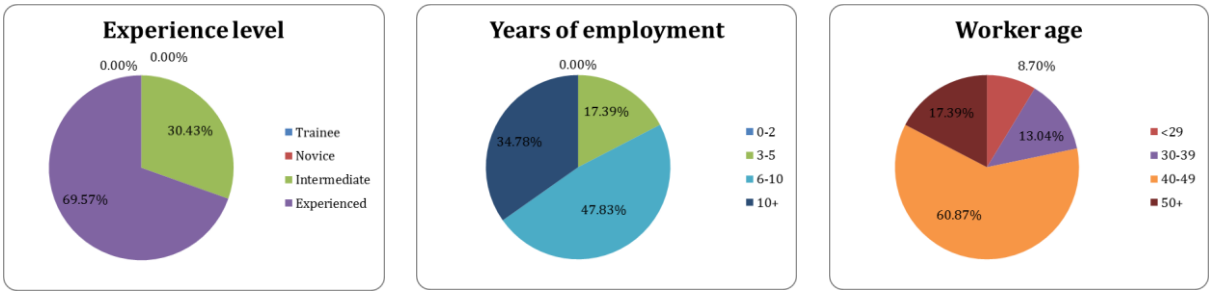
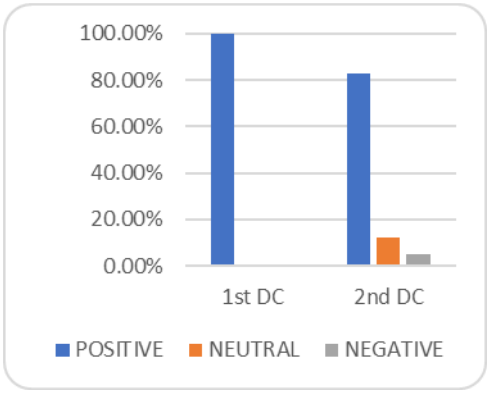
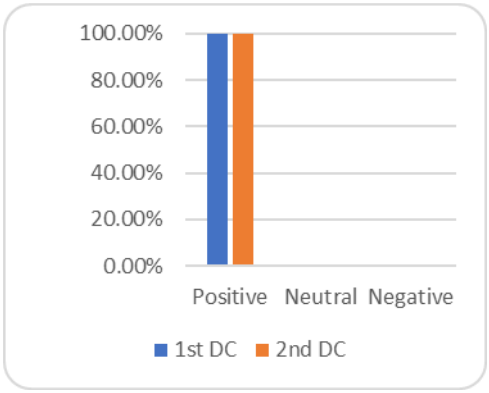


Figure 48 ES3 Decision Makers, Sunlight

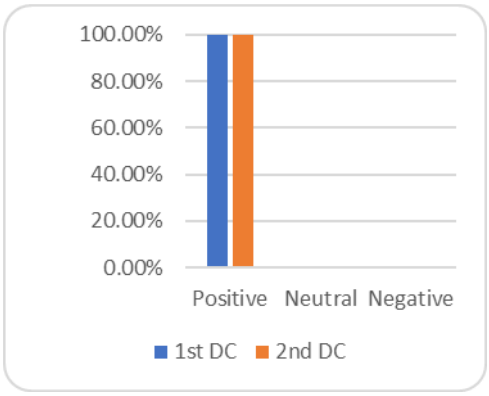
During the 1st Data Collection period at SUNLIGHT 5 decision makers responded for ET6.2 and 5 decision makers responded to ET7.2, while in the 2nd Data Collection period 6 decision makers responded to ET6.2 and 7 decision makers responded to ET7.2.



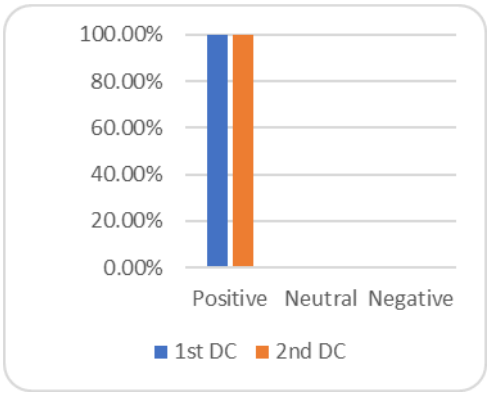
(a) General Evaluation



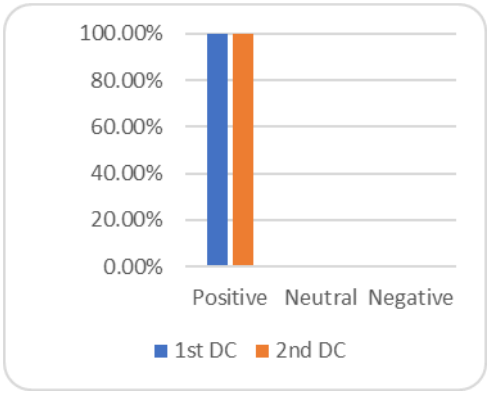
(b) Usability



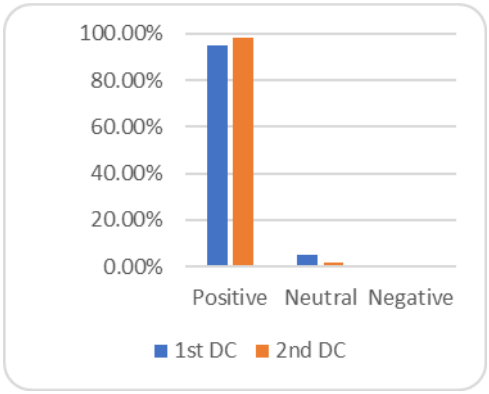
(c) Knowledge Integration



(d) Working Experience



(e) User Acceptance



(f) Overall Impact

Figure 49 ES3-Decision Makers, SUNLIGHT: Supporting Incident Detection & Recognition Operations

The same trend as with the previous evaluation scenarios continues here as well, with the managers giving a lower evaluation in the second data collection in the SUS questionnaire. With regard to the other metrics, no change is reported and their evaluation has been the highest from the beginning.

4.2.4 Evaluation Scenario 4 Results

Evaluation Scenario 4 (Offering “On-the-Job” Training Services) consists of three scenarios (ES4.1 Training environment set-up, ES4.2 Training support – Execution and ES4.3 Training support – Data Analysis). The data collection obtained within this scenario was based on one questionnaire, named On-the-job training in assembly operations (ET8.1 for worker and ET8.2 for decision maker).

4.2.4.1 ES4 Workers' Results

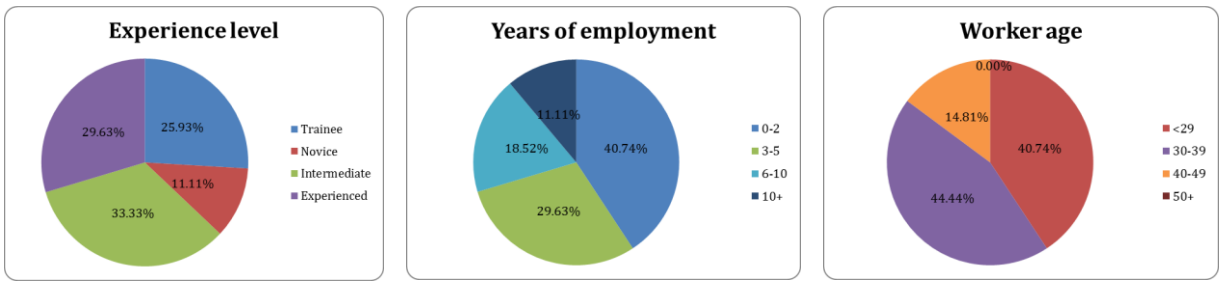
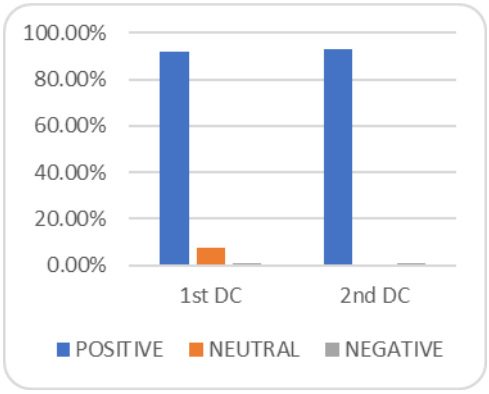
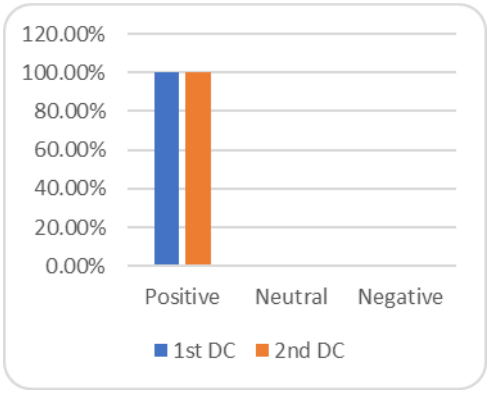


Figure 50 ES4 Workers, Sunlight

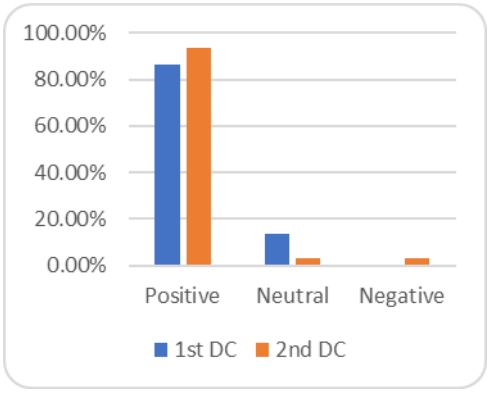
During the 1st Data Collection period at SUNLIGHT 11 workers responded for ET8.1, while in the 2nd Data Collection period 16 workers responded to ET8.1.



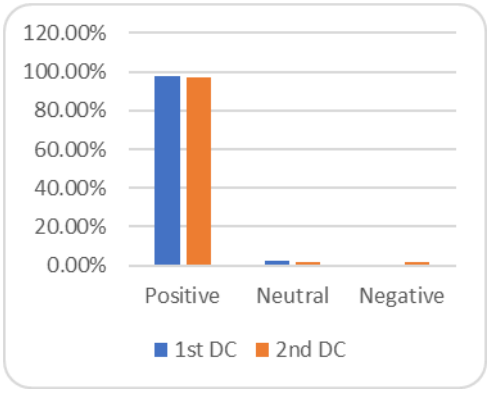
(a) General Evaluation



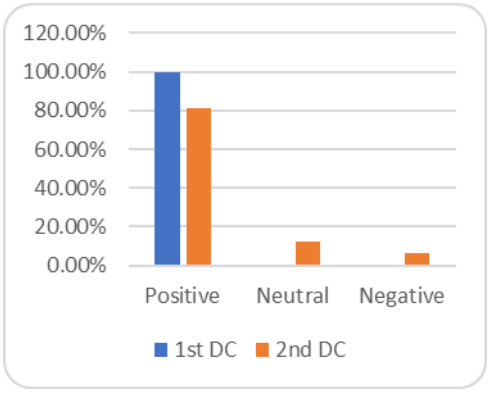
(b) Usability



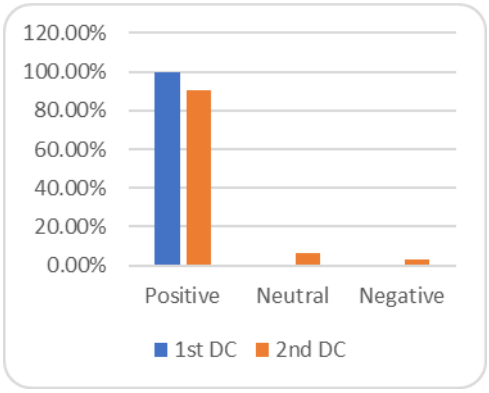
(c) Knowledge Integration



(d) Working Experience



(e) User Acceptance



(f) Overall Impact

Figure 51 ES4-Workers, SUNLIGHT: Offering "On-the-Job" Training Services

4.2.4.2 ES4 Decision Makers' Results

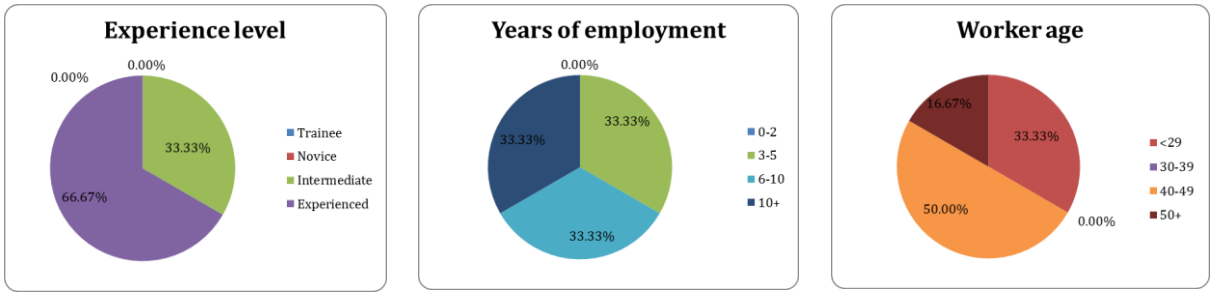
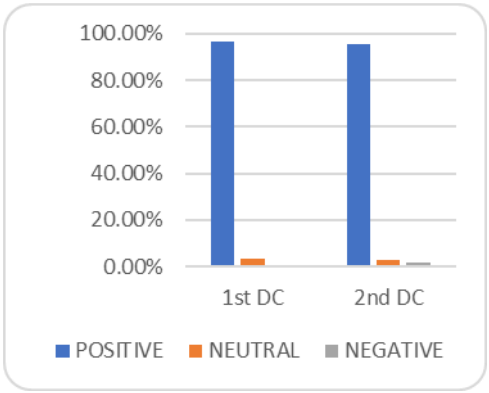
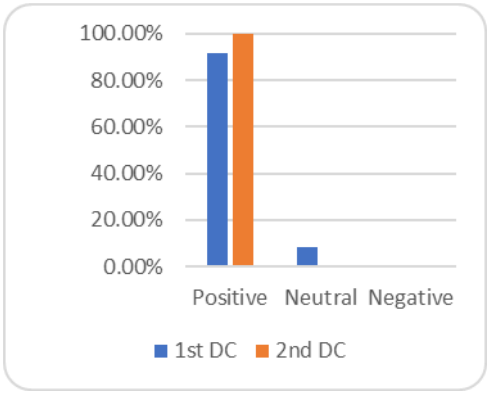


Figure 52 ES4 Decision Makers, Sunlight

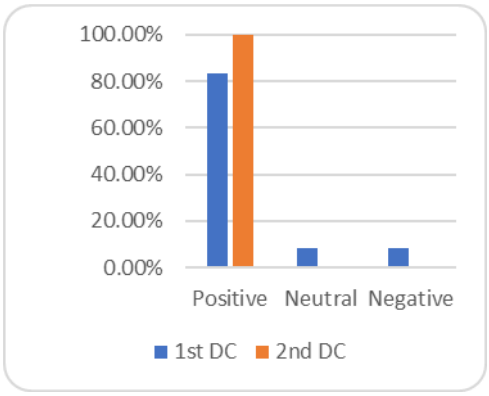
During the 1st Data Collection period at SUNLIGHT 6 decision makers responded for ET8.2, while in the 2nd Data Collection period 7 decision makers responded to ET8.2.



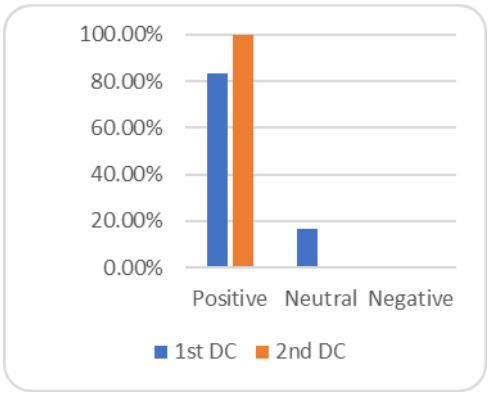
(a) General Evaluation



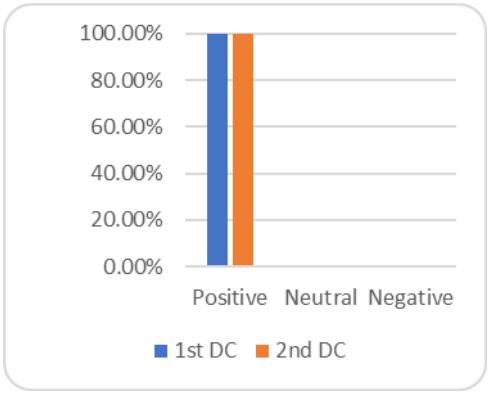
(b) Usability



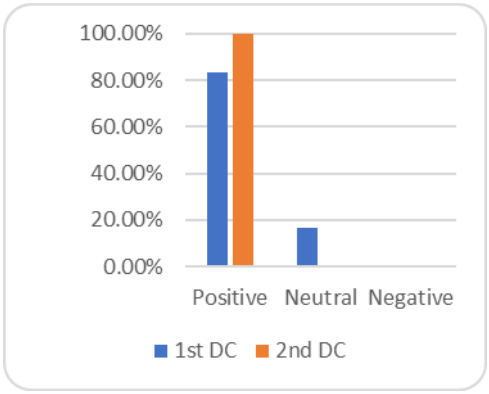
(c) Knowledge Integration



(d) Working Experience



(e) User Acceptance



(f) Overall Impact

Figure 53 ES4-Decisio Makers, SUNLIGHT: Offering “On-the-Job” Training Services

The evaluation of ES4 has been very high from the beginning and no material change is observed in the second data collection either. The separate metrics on the other hand have received consistently higher evaluations, which points to the success of Satisfactory in this scenario.

4.2.5 Evaluation Scenario 5 Results

Evaluation Scenario 5 (Gamification and Collaboration Tools Usage) consists of two scenarios (ES5.1: Gamification Tools Usage and ES5.2: Collaboration Tools Usage). The data collection obtained within this scenario was based on two questionnaires, Gamification in shop floor working environment and Collaboration in shop floor working environment, for workers (ET9.1 and ET5.1) and for decision makers (ET9.2 and ET 5.2).

4.2.5.1 ES5 Workers' Results

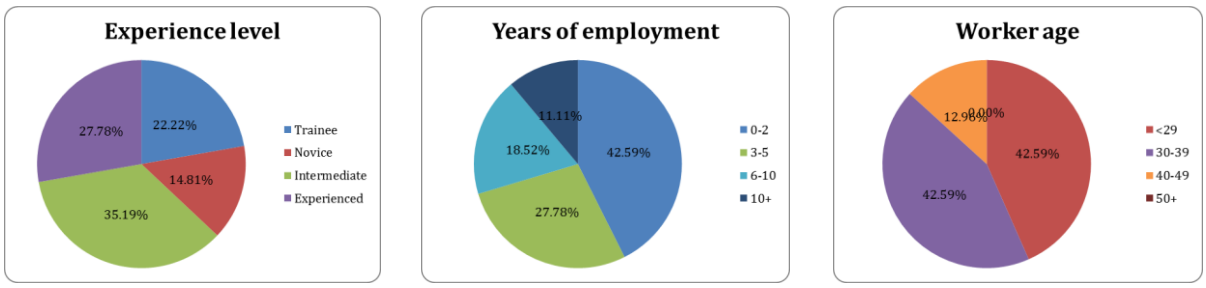
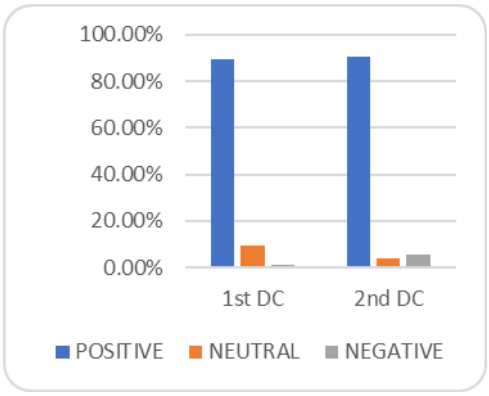
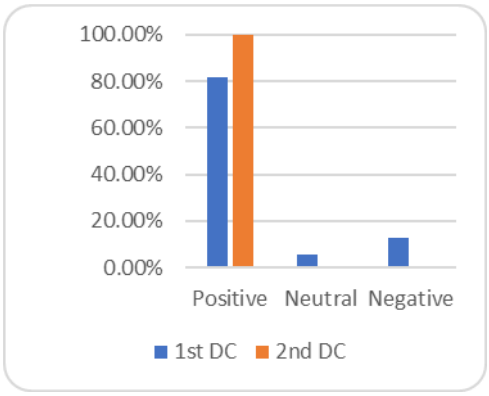


Figure 54 ES5 Workers, Sunlight

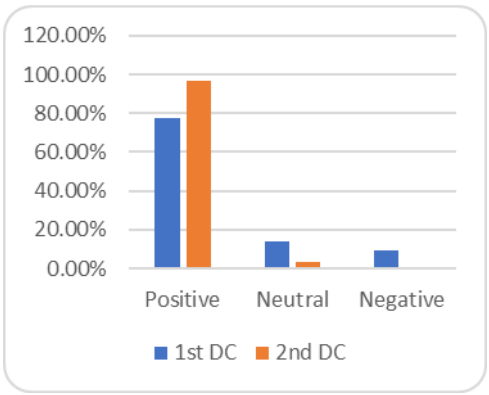
During the 1st Data Collection period at SUNLIGHT 11 workers responded for ET5.1 and 11 workers responded to ET9.1, while in the 2nd Data Collection period 16 workers responded to ET5.1 and 16 workers responded to ET9.1.



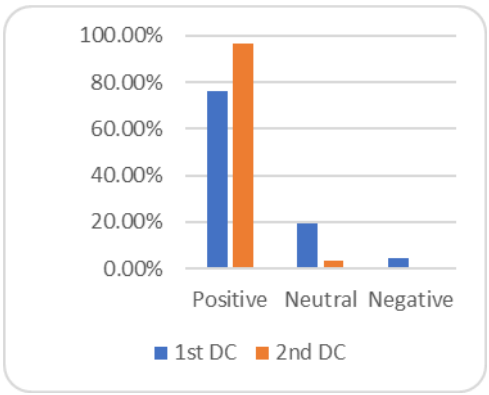
(a) General Evaluation



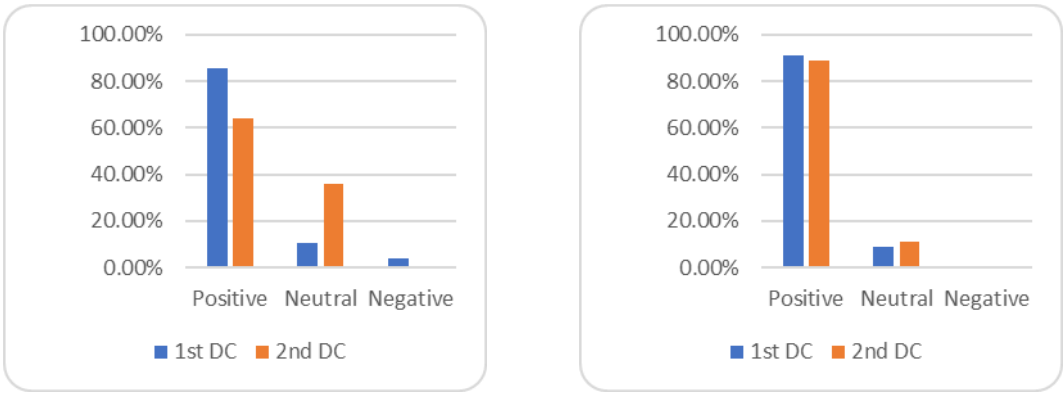
(b) Usability



(c) Knowledge Integration



(d) Working Experience



(e) User Acceptance (f) Overall Impact

Figure 55 ES5-Workers, SUNLIGHT: Gamification and Collaboration Tools Usage

It is unfortunate that the ES5 evaluation has resulted in a negative evaluation from a worker in the second data collection. The value itself is however so low that it could have been influenced by factors outside the Satisfactory framework or could be within the margin of error. As a final explanation, the lower user acceptance of the framework in ES5 may have reflected in this negative evaluation. This is indeed a significant change and steps should be taken to further investigate the reasons why user acceptance decreased in the second data collection.

4.2.5.2 ES5 Decision Makers' Results

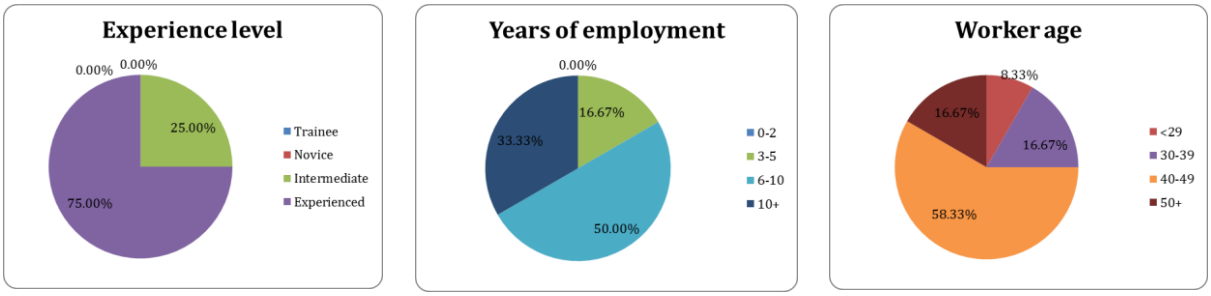
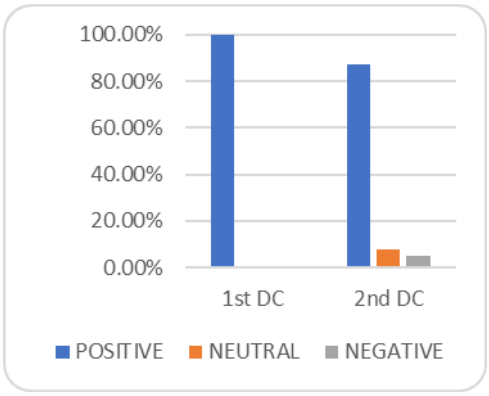
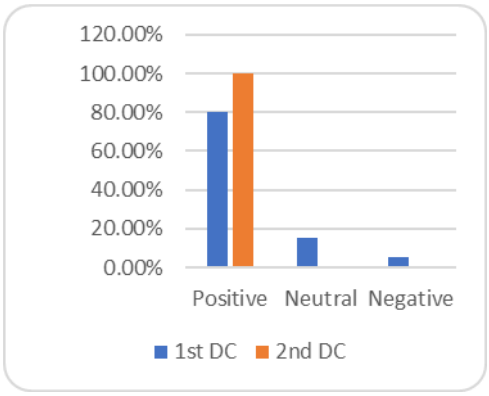


Figure 56 ES5 Decision Makers, Sunlight

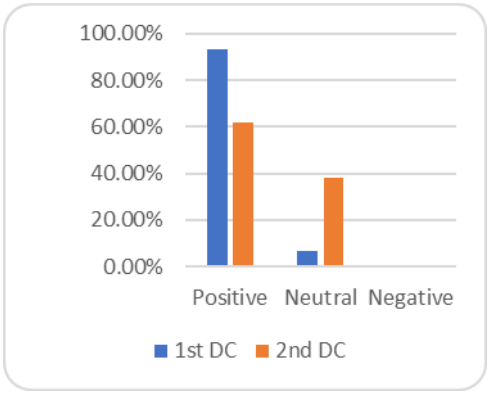
During the 1st Data Collection period at SUNLIGHT 5 decision makers responded for ET5.2 and 5 decision makers responded to ET9.2, while in the 2nd Data Collection period 7 decision makers responded to ET5.2 and 7 decision makers responded to ET9.2.



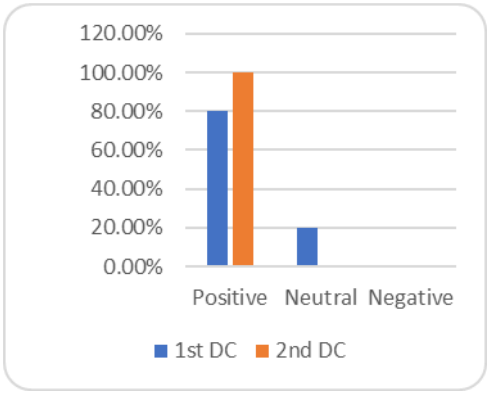
(a) General Evaluation



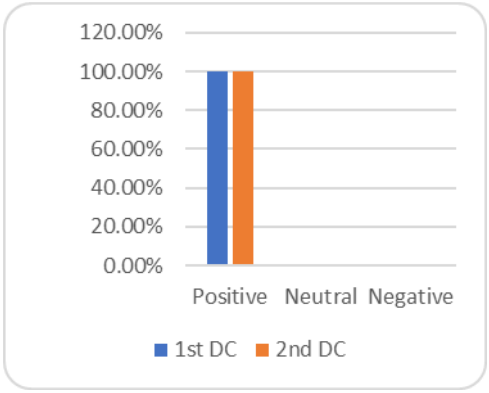
(b) Usability



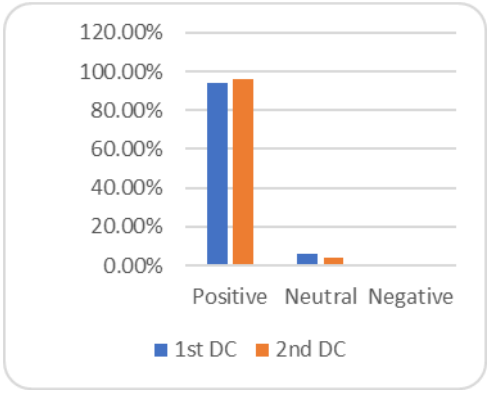
(c) Knowledge Integration



(d) Working Experience



(e) User Acceptance



(f) Overall Impact

Figure 57 ES5-Decision Makers, SUNLIGHT: Gamification and Collaboration Tools Usage

The second data collection highlights that knowledge integration was not satisfactorily achieved in ES5 from the decision makers' point of view. The general evaluation metrics are not much different from what we would expect from previous evaluation scenarios, but it may

be worth to investigate what decision makers expected in terms of knowledge integration, as that seems to be the major factor influencing the lower evaluation.

4.2.6 Impact Check List Results and Analysis

4.2.6.1 Workers' Results

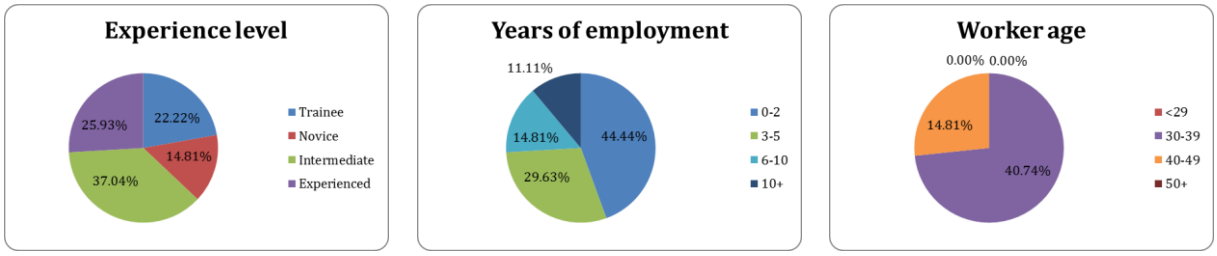
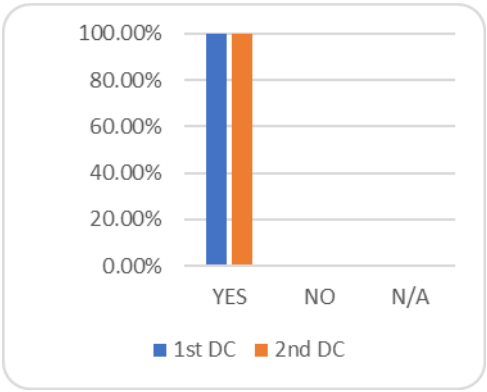
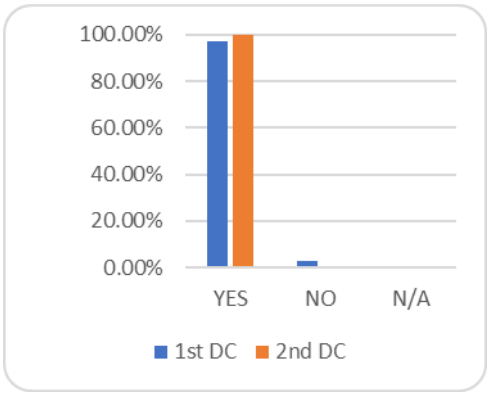


Figure 58 Impact Check List Workers, Sunlight

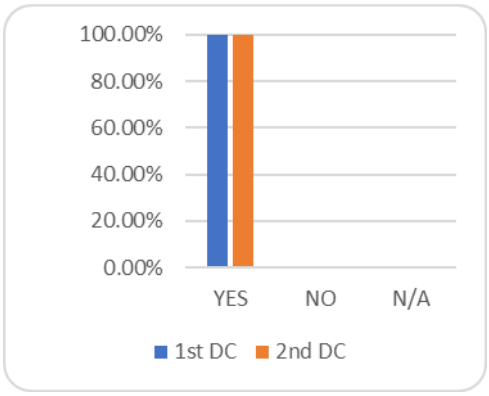
During the 1st Data Collection period at SUNLIGHT6 workers responded for Impact Check List 18 workers responded in the 2nd Data Collection period.



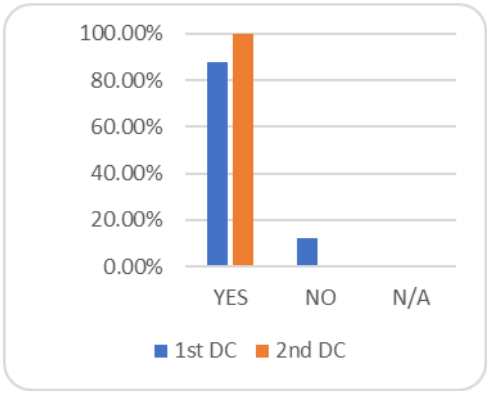
(a) Usability



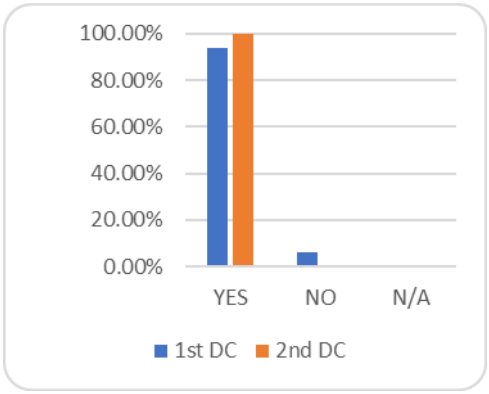
(b) Knowledge Integration



(c) Working Experience



(d) User Acceptance



(e) Overall Impact

Figure 59 Impact Check List -Workers, SUNLIGHT

4.2.6.2 Decision Makers' Results

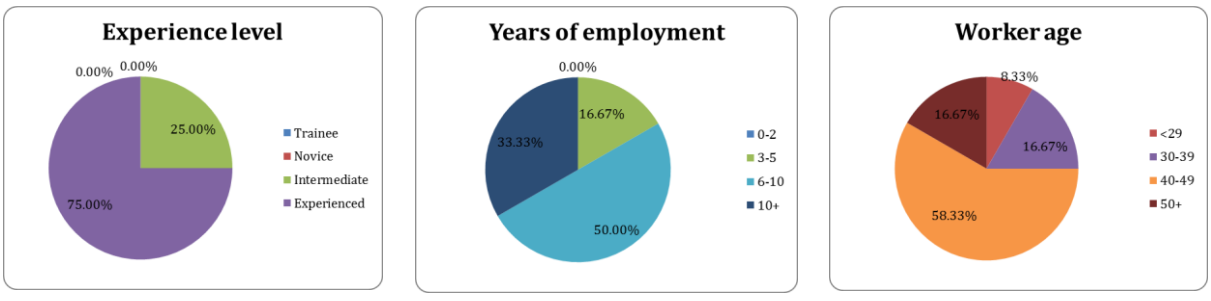
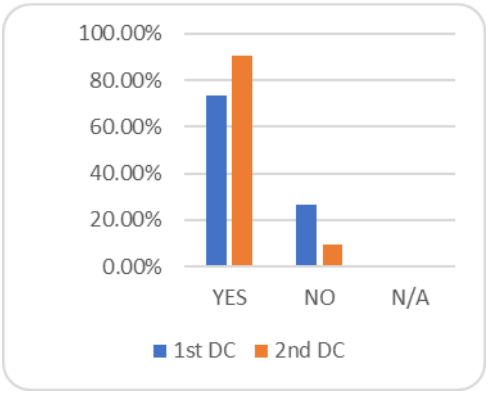
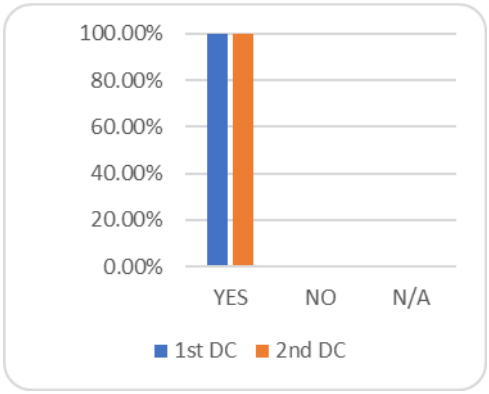


Figure 60 Impact Check List Decision Makers, Sunlight

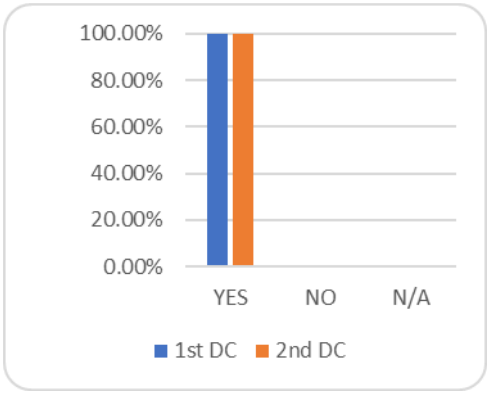
During the 1st Data Collection period at SUNLIGHT 8 decision makers responded for Impact Check List 18 decision makers responded in the 2nd Data Collection period.



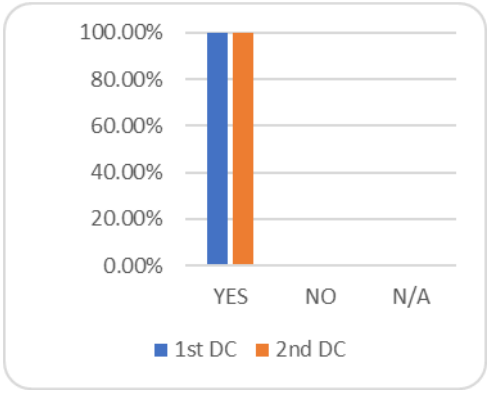
(a) Usability



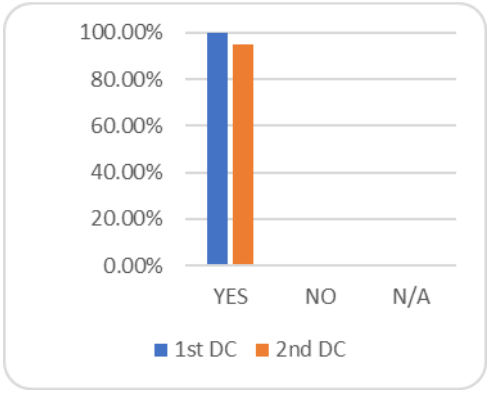
(b) Knowledge Integration



(c) Working Experience



(d) User Acceptance



(e) Overall Impact

Figure 61 Impact Check List -Decision Makers, SUNLIGHT

The impact checklists seem to be positively supported by the Satisfactory framework, as the comparison charts show. No particular attention is needed on this scenario, at least not from

the workers' point of view. These results hold also for decision makers, making this the first scenario where the benefits and expectations seem to have been clearly communicated to both sides.

4.2.7 Overall Results Assessment

The conclusions of Sunlight's experience by using the SatisFactory platform are listed below. This feedback concerns mostly the technology providing partners in order to improve, to enrich or to fix the components, before the final release to the market. The conclusions are listed by three different aspects (i) based on SUS, (ii) based on SatisFactory evaluation criteria and (iii) exploitable products.

4.2.7.1 Conclusions based on SUS

As presented on chapter "*3.1.1 Human-centric Evaluation Methodology*" the method (Brooke 1996) has chosen as the most appropriate for the human-centric evaluation methodology, since it is able to reliably evaluate products and services, even if the sample size is relatively small.

To facilitate the reader's understanding, the calculation of the SUS score is described in this paragraph. In each questionnaire the first 10 questions, after the demographic questions, are used to calculate SUS score. As presented on the prologue of this chapter, each question has 5 possible responses which are referring to (1) "Strongly Agree", (2) "Agree", (3) "Neither agree nor disagree", (4) "Disagree" and (5) "Strongly Disagree". Half questions are negative questions and the other half are positive. More specifically, the 1, 3, 5, 7 and 9 are positive and the 2, 4, 6, 8 and 10 are negative questions. To obtain the SUS score, first, if the question is positive subtract 1 from the response and if it is negative subtract the response from 5. Secondly, sum up the 10 numbers and multiply by 2.5. The SUS score range is from 0 to 100.

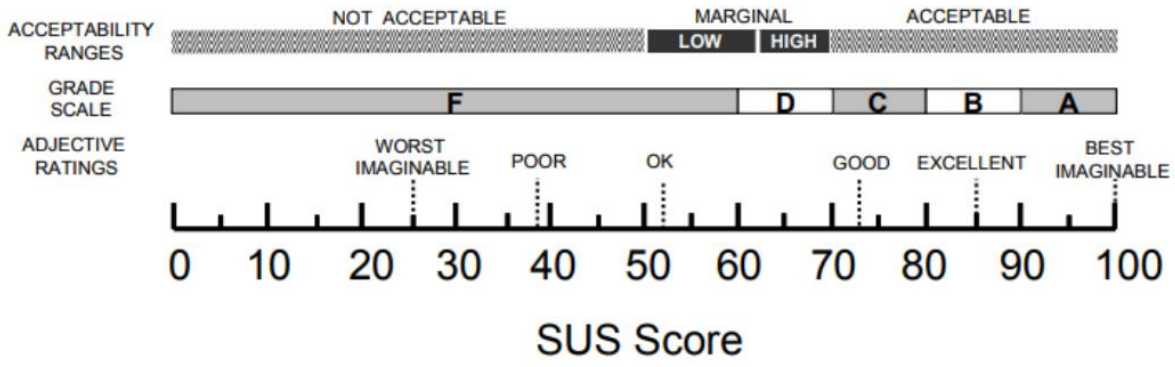


Figure 62 A comparison of the adjective ratings, acceptability scores, and school grading scales, in relation to the average SUS score

Bangor et al. (Bangor 2009) conducted an extensive study in order to interpret the SUS score. They defined 3 indicators using as reference the SUS score, (i) Acceptability ranges[4], (ii) Grade scales and (iii) Adjective ratings as shown on Figure 62. According to Bangor et al. and the SUS scores extracted from the questionnaires as show on Table 12Table 12 SUS scores at Sunlight, the results may be characterized as accepted regarding the acceptability ranges, B-C grade regarding the grade scales and good-excellent regarding the adjective rating.

Table 12 SUS scores at Sunlight

ES	ET	Who	1st	2nd
1	1	W (1.1)	81.6	81.8
1	1	DM (1.2)	74.5	70
1	2	W (2.1)	83.6	82.2
1	2	DM (2.2)	84.5	83.8
2	3	W (3.1)	84.5	84.6
2	3	DM (3.2)	86	87.1
2	4	W (4.1)	83.2	82.7
2	4	DM (4.2)	87.1	86.8
3	6	W (6.1)	82.7	83
3	6	DM (6.2)	89.5	80
3	7	W (7.1)	83.4	83
3	7	DM (7.2)	87	85.7
4	8	W (8.1)	81.8	85.9
4	8	DM (8.2)	81.7	85.7
5	5	W (5.1)	83.2	83.4
5	5	DM (5.2)	87.5	82.9
5	9	W (9.1)	80.7	84.8
5	9	DM (9.2)	90.5	87.5

The results seems to be in a high level, considering that the “products” are not at a market ready stage, especially during the 1st data collection. These scores were not given only by goodwill but also they are biased, as the workers stated, from the excitement by the use of the futuristic technology. Many of the worker’s, especially the older, during the presentation

[4] “Acceptability ranges”, first introduced in Bangor et al. (Bangor 2008)

were incredulous that the present devices were able to do what presented. They were really amazed, and this excitement affected the scores.

At the 2nd data collection, the SUS scores are reduced but not noticeable. Many changes were made the period between the data collections and most of the time the components were unavailable due to improvements or bug fixing. Despite the fact that, each actor spent a small amount of time with each component the score remained high. The actors stated that they noticed that the devices or the software were not perfect, but they gave a high score because they liked the avocation with the platforms. It is worth mentioning that the excitement remained during the whole period and personnel that were not involved to the SatisFactory project were curious about the devices and willing to use them.

4.2.7.2 Conclusions based on SatisFactory evaluation criteria

As mentioned in the previous paragraph the first 10 questions after the demographic questions were used to calculate the SUS score. The other 10 were used for SatisFactory's evaluation criteria.

The scores on SatisFactory evaluation criteria are even higher than the SUS score. This is because during the results analysis the 5 possible responses at each question were grouped in 3 categories. The responses "Strongly Agree" and "Agree" were grouped to "Positive" and the responses "Disagree" and "Strongly Disagree" grouped to "Negative". The evaluators biased by goodwill avoided to use the answers "Disagree" and "Strongly Disagree", this lead the overwhelming majority of the responses to be "Positive". In many cases, the score is 100% "Positive", this does not mean that the participants were fully satisfied but it happened due to the analysis process that described above.

On the Table 13 to Table 17 are only the percentage of "Positive" that were given by workers (W) and decision makers (DW) separately, during the 1st and the 2nd evaluation process at each evaluation scenario (ES).

4.2.7.2.1 Conclusions for Usability

Table 13 Positive feedback for the Usability Criterion at Sunlight

ES	Who	1st	2nd
1	W	84.09	65.28
1	DM	95	100
2	W	88.73	98.82
2	DM	93.33	97.62
3	W	87.88	97.92
3	DM	100	100
4	W	91.67	100
4	DM	81.82	100

5	W	81.82	100
5	DM	80	100

The "Usability Criterion" introduced to identify the suitability, the learnability and the applicability. The results are high and in some ESs are 100%, this means that the evaluators approve the usability of the toolkits. The training sessions and live demonstrations by the developers of the most toolkits, helped a lot the involved actors to learn quickly, how to use the toolkits.

At the 2nd evaluation the scores are even higher, and we suppose that this occurs because the involved actors got familiarized, with the toolkits.

4.2.7.2.2 Conclusions for Knowledge Integration

Table 14 Positive feedback for the Knowledge Integration Criterion at Sunlight

ES	**Who**	**1st**	**2nd**
1	W	65.91	48.61
1	DM	92	80
2	W	70.45	68.75
2	DM	83.33	66.67
3	W	87.88	97.92
3	DM	100	100
4	W	83.33	100
4	DM	77.27	96.88
5	W	77.27	96.88
5	DM	93.33	61.9

The "Knowledge Integration Criterion" is focusing on the toolkits that spread info from sensors or users. It is evaluating the proper exploitation of the information.

As shown on the Table 14 the information in ES1 and ES2 the score dropped significantly, at the second evaluation session. During the interviews, the evaluators stated that despite the improvements, they expected the content concerning the assembly line and the maintenance to be much more enriched. Their expectations did not fulfil and this is reflected to the scores. Concerning the ES5 for decision makers, they stated that the platform during the 1st evaluation session was responding faster, until the 2nd evaluation the real-time information had delay sometimes.

4.2.7.2.3 Conclusions for Perception of Working Experience

Table 15 Positive feedback for the Perception of Working Experience Criterion at Sunlight

ES	Who	1st	2nd
1	W	90.91	44.44
1	DM	100	100
2	W	85.91	87.5
2	DM	88.89	100
3	W	90.91	93.75
3	DM	100	100
4	W	83.33	100
4	DM	76.36	96.88
5	W	76.36	96.88
5	DM	80	100

The actual working experience with SatisFactory platform, concerning changes to social and environmental aspects, like attitude of workers, ergonomics, safety and quality of training assistance were evaluation by the “Perception of Work Experience Criterion”.

As shown on Table 15, the evaluators regarding all ESs except ES1 for workers was really pleased by the use and the improvements made to the toolkits. The technical improvements of the tools is reflected to the score. The workers who interviewed concerning the ES1 mentioned that the toolkit was fine, but they did not have the available time to explore it as they would like. Moreover, the app became slower at some procedures and this made bad impression, especial when a worker needed to check something fast.

4.2.7.2.4 Conclusions for User Acceptance

Table 16 Positive feedback for the User Acceptance Criterion at Sunlight

ES	Who	1st	2nd
1	W	96.97	96.3
1	DM	100	100
2	W	90.91	95.31
2	DM	88.89	100
3	W	89.39	96.88

3	DM	100	100
4	W	100	100
4	DM	100	100
5	W	85.71	64.29
5	DM	100	100

The “User Acceptance Criteria” is evaluating the willing of the involved actors who used the toolkits of SatisFactory platform to reuse them or even more to buy them.

The scores on Table 16 indicates the satisfaction that has been created to the involved actors by using the SatisFactory platform. Only the ES5 for workers is reduced at the 2nd evaluation. The workers do not have office and as a consequence they do not have easy access to a computer. In order to access the collaboration platform, they can do it by shared terminals or tablets. However, they stated that they are intended to use the platform as frequent as possible although the collaboration platform is only accessible through the company network. This limitation occurs because of the strict security rules that are applied to the company’s network access.

4.2.7.2.5 Conclusions for Overall Impact

Table 17 Positive feedback for Overall Impact Criterion at Sunlight

ES	**Who**	**1st**	**2nd**
1	W	74.55	75.56
1	DM	80	78.57
2	W	56.36	58.75
2	DM	56.67	40
3	W	100	100
3	DM	95	98.21
4	W	83.33	100
4	DM	90.91	89.06
5	W	90.91	89.06
5	DM	94.29	95.92

The “Overall Impact” is positive, the scores are showing that involved actors are pleased from the SatisFactory platform. The ES2s are low. These ESs are concerning mostly the Maintenance department. At the interviews they stated that they got a very positive impression about it. However, because the maintenance personnel have to move around the

factory, it is difficult for them to carry extra equipment. Especially, when the equipment is expensive and fragile like the AR glasses. The other departments did not mentioned problems like that.

4.2.7.3 Connection to exploitable products and results of data collection

The toolkits / products of SatisFactory platform that were used from the involved actors, made really good impression and the advantages of the toolkits use appeared even before the first data collection, when the toolkits had to be improved and fix many bugs. Unfortunately, despite that there were some weak points that were reported from the actors, they recognize that they will be eliminated if the use of the toolkits will be extended to more production lines and more users.

The following paragraph describes the pros and cons regarding the use of toolkits. Opinions and aspects which are not feasible to measure are presented below.

Semantics and Context-aware knowledge shop floor analysis engine

The context-aware were used mostly by workers. The most remarkable were the gesture control were the worker was able to change the display without the need of removing the gloves or to wash the hands first. Gesture control were one of the components that were used almost from all worker. Semantics engine was running into the background, but the decision makers were able to check its suggestions. They pointed out that in the future it would probably more useful when more actors will use these tools.

Real-time localization of workers, tools and machines

This product was mostly used by decision makers. They stated that it was helpful and the information that were provided actually enhanced the productivity. The ability to access the data from devices like tablets or smartphones was really helpful. It would be really better if the implementation were at a bigger scale, for example to have more tags in order to track most of the workers, the area that Localization Manager covers to be larger, same for depth cameras.

Dynamic Re-adaptation of Production Facilities

This component tried to be the right hand of each decision maker. Various data concerning different procedures and resources were easily accessible. Nice interface and easy to use. The amount of the collected data was limited due to the short period of use. More data will be collected as the tool will continue to be used by the actors. The available data does not concern only the use but also the bug fixing. The actors stated that it is difficult to change the procedures by involving many different tools at once. The main purpose is to keep on the production line working smoothly. They used the tools but the fully adaptation of the tools needs more time.

Integrated shop floor DSS

This toolkit was running in the background and only the output was displayed through HMI mainly from an internet browser, but also from app on tablet or smart phone. The iDSS in

order to provide suggestions, need options to choose. Despite the fact that there were more than 20 actors involved were not enough (for what????), concerning the factory's needs.

HR workload balancing toolkit (Incident management) and Feedback Engine (incident detection)

Workload monitoring and instance feedback is desirable to all decision makers. The approach of SatisFactory platform through the HR workload balancing toolkit and Feedback engine was interesting. Once more the small scale of the implementation was limiting the available options.

On-the-job training toolkit

One of the most impressive tools. The augmented reality and especially by using the glasses which is something very innovative and the workers were very pleased from the experience. The On-the-job training toolkit saved time from the experienced employs that are acting as trainers, but in order to expand the training process to other production lines it needs a lot of work in the background.

Gamification/Collaboration platform for manufacturing enterprises

Both of these platforms are very interesting. Especially the gamification is something that can be really useful and there are many ways to use it. Engaging with collaboration applications and games, employs must devote time coming from their working or break time. At the beginning, people were quite curious to explore the capabilities but later they realize that they got delayed from the work or spend a significant amount of time from their break time. It would be more helpful if they could do it during the leisure time or from home. This needs to be permitted by the company's IT department.

Middleware for Smart Factories and Smart Sensor Network for Industrial Applications

The existence of Middleware is unknown to all involved actors, since it is running in the back ground. On the other side, the sensors especially those who may accessed by gamification made really good impression even the simple ones, like environmental parameters measurement. Legacy sensors are something usual at a factory's shop flop, but devices like depth cameras, with collision detection or gesture recognition is something unusual and very impressive.

4.3 COMPARISON OF THE OVERALL RESULTS

This chapter is a final comparison of the evaluation results given from the two pilots and the one pre-pilot that participated in the project. The feedback received from all three end-users is from the questionnaires, information collected throughout feedback that was edited with specific methodology referred again in the next sub-chapter for the ease of the reader.

As already stated, it was very important to have this stage of evaluation because both from the answers but even more important from the live testing and observation of the users, resulted in both revealing problematic conditions of the products and improving their state in many sectors.

SatisFactory project was really successful in providing cutting-edge products because of the continuous feedback and improvement points. It is important to note that one of the pilots, COMAU, took the initiative to communicate the project's work and help in the consolidation of development.

4.3.1 Conclusions based on SUS

Between the two pilots and the pre-pilot SatisFactory used to install and test the implemented software, there are interesting notifications that denote how end users react differently from place to place. For the 1st Data Collection when the applications of the proposed system were at initial stage, in CPERI (pre-pilot) the evaluation was not good based on the method that is presented in chapter "*3.1.1 Human-centric Evaluation Methodology*" (Brooke 1996). At Sunlight, employees were enthusiastic about the presentation of early-stage tools and really impressed concerning the capabilities shown. In COMAU there was a critical evaluation in a constructively way that highlighted many improvement points and fostered the platform's growth and optimization.

In 2nd Data Collection, the evaluation changed in all three areas. CPERI was much more satisfied with the evolution of the platform than in first time and COMAU gave a very positive and supporting evaluation. At Sunlight scores were a little lower but not in a noticeable level.

Table 18 Workers General Evaluation

		SUNLIGHT	CPERI	COMAU
ES1-W	POSITIVE	84.80%	82.87%	46.00%
	NEUTRAL	9.48%	12.63%	26.00%
	NEGATIVE	5.71%	4.50%	28.00%
ES2-W	POSITIVE	91.81%	73.33%	N/A
	NEUTRAL	6.32%	14.02%	N/A
	NEGATIVE	1.87%	12.65%	N/A
ES3-W	POSITIVE	91.85%	63.00%	51.00%
	NEUTRAL	6.67%	12.50%	29.00%
	NEGATIVE	1.48%	24.50%	20.00%
ES4-W	POSITIVE	92.58%	96.25%	54.29%
	NEUTRAL	6.68%	3.75%	31.43%
	NEGATIVE	0.74%	0.00%	14.29%
ES5-W	POSITIVE	90.00%	82.00%	52.86%
	NEUTRAL	8.89%	15.00%	18.00%
	NEGATIVE	1.11%	3.00%	29.14%

Table 19 Decision Makers General Evaluation

		SUNLIGHT	CPERI	COMAU
ES1-DM	POSITIVE	71.43%	47.00%	55.71%
	NEUTRAL	18.57%	35.50%	30.00%
	NEGATIVE	10.00%	17.50%	14.29%
ES2-DM	POSITIVE	97.46%	65.83%	N/A
	NEUTRAL	2.54%	22.92%	N/A
	NEGATIVE	0.00%	11.25%	N/A
ES3-DM	POSITIVE	97.39%	75.00%	45.83%
	NEUTRAL	2.16%	20.00%	35.00%
	NEGATIVE	0.45%	5.00%	19.17%
ES4-DM	POSITIVE	96.15%	53.33%	53.33%
	NEUTRAL	3.08%	40.00%	35.00%
	NEGATIVE	0.77%	6.67%	11.67%
ES5-DM	POSITIVE	96.67%	85.00%	56.67%
	NEUTRAL	2.92%	15.00%	24.17%
	NEGATIVE	0.42%	0.00%	19.17%

4.3.2 Conclusions based on SatisFactory evaluation criteria

In CPERI shop-floor the results that were acquired from the evaluation process were successful. The method that was followed contained specific questions that made it possible for technology providers to understand the view of the end users per criterion. The criterions are:

1) Usability;
2) Knowledge capitalization inside the platform;
3) User experience;
4) Acceptability of the solutions;
5) Impact

In the second iteration of the development of tools there was a great improvement as a lot of detected issues were corrected. These issues were revealed from this evaluation procedure.

In Sunlight there were a higher than the SUS score that was the result of a grouping technique that was used to the answers. The 5 possible responses at each question were grouped in 3 categories as described at 4.1.7.2.

At COMAU with the use of the same evaluation process, the questions asked, revealed similar results while the whole process resulted in a positive feedback for the project's platform.

Table 20 Workers SatisFactory Specific Evaluation

		Usability	Knowledge Integration	Working Experience	User Acceptance	Overall Impact	
ES1-W	POSITIVE	84.04%	65.91%	90.91%	96.97%	74.55%	SUNLIGHT
	NEUTRAL	14.87%	6.07%	10.56%	4.72%	6.28%	
	NEGATIVE	0.89%	38.64%	3.57%	2.30%	18.55%	
	POSITIVE	78.03%	48.86%	93.18%	67.17%	78.48%	CPERI
	NEUTRAL	17.42%	17.42%	6.82%	11.87%	8.94%	
	NEGATIVE	4.55%	33.71%	0.00%	20.96%	12.58%	
	POSITIVE	50.00%	33.33%	58.33%	75.00%	83.33%	COMAU
	NEUTRAL	33.33%	33.33%	16.67%	25.00%	16.67%	
	NEGATIVE	16.67%	33.33%	25.00%	0.00%	0.00%	
ES2-W	POSITIVE	93.24%	69.41%	84.62%	92.45%	55.38%	SUNLIGHT
	NEUTRAL	5.22%	9.26%	13.46%	6.59%	9.15%	
	NEGATIVE	1.54%	21.33%	1.92%	0.96%	35.47%	
	POSITIVE	82.73%	59.85%	74.24%	68.64%	44.55%	CPERI
	NEUTRAL	13.64%	19.70%	25.76%	19.09%	28.03%	
	NEGATIVE	3.64%	20.45%	0.00%	12.27%	27.42%	
	POSITIVE	N/A	N/A	N/A	N/A	N/A	COMAU
	NEUTRAL	N/A	N/A	N/A	N/A	N/A	
	NEGATIVE	N/A	N/A	N/A	N/A	N/A	
ES3-W	POSITIVE	93.21%	86.42%	92.59%	93.21%	98.15%	SUNLIGHT
	NEUTRAL	4.32%	11.11%	6.17%	5.56%	1.85%	
	NEGATIVE	2.47%	2.47%	1.23%	1.23%	0.00%	
	POSITIVE	81.67%	76.67%	80.00%	73.33%	70.00%	CPERI
	NEUTRAL	10.00%	16.67%	6.67%	20.00%	30.00%	
	NEGATIVE	5.00%	6.67%	13.33%	6.67%	0.00%	
	POSITIVE	50.00%	66.67%	65.00%	36.67%	60.00%	COMAU
	NEUTRAL	23.33%	13.33%	13.33%	33.33%	10.00%	
	NEGATIVE	26.67%	20.00%	21.67%	30.00%	30.00%	
ES4-W	POSITIVE	100.00%	90.74%	97.22%	88.89%	94.44%	SUNLIGHT
	NEUTRAL	0.00%	7.41%	1.85%	7.41%	3.70%	
	NEGATIVE	0.00%	1.85%	0.93%	3.70%	1.85%	
	POSITIVE	100.00%	75.00%	68.75%	87.50%	75.00%	CPERI
	NEUTRAL	0.00%	18.75%	28.13%	12.50%	25.00%	
	NEGATIVE	0.00%	6.25%	3.13%	0.00%	0.00%	
	POSITIVE	71.43%	78.57%	64.29%	85.71%	71.43%	COMAU
	NEUTRAL	28.57%	14.29%	32.14%	0.00%	21.43%	

	NEGATIVE	0.00%	7.14%	3.57%	14.29%	7.14%	
ES5-W	POSITIVE	86.67%	87.04%	88.68%	87.83%	87.96%	SUNLIGHT
	NEUTRAL	8.15%	9.26%	9.47%	10.58%	12.04%	
	NEGATIVE	5.19%	3.70%	1.85%	1.59%	0.00%	
	POSITIVE	64.00%	50.00%	70.00%	71.43%	75.00%	CPERI
	NEUTRAL	28.00%	50.00%	30.00%	17.14%	20.00%	
	NEGATIVE	8.00%	0.00%	0.00%	11.43%	5.00%	
	POSITIVE	33.14%	0.00%	34.29%	46.94%	67.14%	COMAU
	NEUTRAL	24.00%	44.29%	20.00%	19.59%	17.14%	
	NEGATIVE	42.86%	55.71%	45.71%	33.47%	15.71%	

Table 21 SatisFactory Specific Evaluation

		Usability	Knowledge Integration	Working Experience	User Acceptance	Overall Impact	
ES1-DM	POSITIVE	100.00%	80.00%	100.00%	100.00%	78.57%	SUNLIGHT
	NEUTRAL	0.00%	0.00%	0.00%	0.00%	0.00%	
	NEGATIVE	0.00%	20.00%	0.00%	0.00%	21.43%	
	POSITIVE	80.00%	68.00%	46.67%	72.50%	80.00%	CPERI
	NEUTRAL	15.00%	24.00%	23.33%	27.50%	5.00%	
	NEGATIVE	5.00%	8.00%	30.00%	0.00%	15.00%	
	POSITIVE	85.71%	66.67%	57.14%	64.29%	85.71%	COMAU
	NEUTRAL	7.14%	23.81%	42.86%	35.71%	14.29%	
	NEGATIVE	7.14%	9.52%	0.00%	0.00%	0.00%	
ES2-DM	POSITIVE	95.83%	74.36%	94.87%	94.87%	64.62%	SUNLIGHT
	NEUTRAL	4.17%	0.00%	5.13%	5.13%	10.77%	
	NEGATIVE	0.00%	25.64%	0.00%	0.00%	24.62%	
	POSITIVE	56.94%	41.67%	61.11%	91.67%	60.00%	CPERI
	NEUTRAL	43.06%	19.44%	38.89%	8.33%	13.33%	
	NEGATIVE	0.00%	38.89%	0.00%	0.00%	26.67%	
	POSITIVE	N/A	N/A	N/A	N/A	N/A	COMAU
	NEUTRAL	N/A	N/A	N/A	N/A	N/A	
	NEGATIVE	N/A	N/A	N/A	N/A	N/A	
ES3-DM	POSITIVE	100.00%	100.00%	100.00%	100.00%	96.88%	SUNLIGHT
	NEUTRAL	0.00%	0.00%	0.00%	0.00%	3.13%	
	NEGATIVE	0.00%	0.00%	0.00%	0.00%	0.00%	
	POSITIVE	93.75%	91.67%	100.00%	87.50%	87.50%	CPERI
	NEUTRAL	6.25%	8.33%	0.00%	12.50%	12.50%	
	NEGATIVE	0.00%	0.00%	0.00%	0.00%	0.00%	

	POSITIVE	54.17%	83.33%	66.67%	45.83%	50.83%	**COMAU**
	NEUTRAL	25.00%	0.00%	16.67%	37.50%	23.75%	
	NEGATIVE	20.83%	16.67%	16.67%	16.67%	25.42%	
ES4-DM	**POSITIVE**	96.15%	96.15%	96.15%	96.15%	96.15%	**SUNLIGHT**
	NEUTRAL	3.08%	3.08%	3.08%	3.08%	3.08%	
	NEGATIVE	0.77%	0.77%	0.77%	0.77%	0.77%	
	POSITIVE	50.00%	66.67%	83.33%	100.00%	100.00%	**CPERI**
	NEUTRAL	33.33%	16.67%	0.00%	0.00%	0.00%	
	NEGATIVE	16.67%	16.67%	16.67%	0.00%	0.00%	
	POSITIVE	78.57%	60.71%	92.86%	85.71%	57.14%	**COMAU**
	NEUTRAL	21.43%	14.29%	0.00%	0.00%	28.57%	
	NEGATIVE	0.00%	25.00%	7.14%	14.29%	14.29%	
ES5-DM	**POSITIVE**	91.67%	91.67%	91.67%	100.00%	95.24%	**SUNLIGHT**
	NEUTRAL	6.25%	8.33%	8.33%	0.00%	4.76%	
	NEGATIVE	2.08%	0.00%	0.00%	0.00%	0.00%	
	POSITIVE	87.50%	50.00%	100.00%	100.00%	71.43%	**CPERI**
	NEUTRAL	12.50%	50.00%	0.00%	0.00%	28.57%	
	NEGATIVE	0.00%	0.00%	0.00%	0.00%	0.00%	
	POSITIVE	41.67%	22.22%	50.00%	66.67%	57.14%	**COMAU**
	NEUTRAL	16.67%	44.44%	33.33%	20.00%	23.81%	
	NEGATIVE	41.67%	33.33%	16.67%	13.33%	19.05%	

4.3.3 Connection to exploitable products and results of data collection

Since the beginning of the project and till its completion, the general idea was to implement adaptive and exploitable products. Both pilots and pre-pilot gave a very supportive evaluation to the platforms' tools highlighting specifically for each one the advantages according to their opinion. A fruitful description of the exploitable products is given by COMAU at 4.1.7.3 while Sunlight expresses their opinion in 4.2.7.3. For CPERI, there is an extensive and informative description in D5.2 at section 5.7.3 for anyone that wants to read it.

5. LESSONS LEARNED

In this chapter, the technology providers who developed the components are describing the lessons learned from their involvement to the SatisFactory project. The chapter is organised in six paragraphs which response to six stages of product development, (i) Requirement gathering and analysis, (ii) Design, (iii) Development, (iv) Testing, (v) Deployment, (vi) Maintenance. Each technology partner states difficulties and achievements from their involvement to the SatisFactory project.

5.1 REQUIREMENT GATHERING AND ANALYSIS

5.1.1 CERTH

Difficulties	
Gamification Platform	
Problem	There wasn't a UI environment for a user to set a gamified action. All actions were given hardcoded points.
Impact	There was no flexibility in changing awards of gamified actions according to feedback
Recommendation	Implementation of UI environment for the administrator of the platform, to be able and created gamified actions according to needs.
AR In-Factory Training Platform	
Problem	The requirement gathering on both pilot sites when putting together the BSCs didn't fully address deployment factors stemming from space restrictions, WiFi existence and network connectivity in general n the work area and size of elements to be represented in 3D
Impact	The problem created the necessity for the Presentation tool to be able to work offline, as well as create 3D models that are too big to fit entirely in the AR visualization
Recommendation	Better communication with end users is needed in order to provide network connectivity and understanding of how to best represent 3D models of components in AR and how they are to be deployed in existing spaces. Set intermediary deadlines for refinement of requirements as a work in progress.
Human Resources re-adaptation engine	
Problem	According to the initial requirements, the locations of employees were not considered when assigning tasks, even though the relevant

	information could be acquired.
Impact	Localization information regarding the current positions of employees is an important factor, especially in case when new critical tasks occur, which helps to reduce response times.
Recommendation	Implementation of distance computation which is considered as an additional factor when calculating the cost of each assignment solution.

Achievements	
AR In-Factory Training Platform	
Success	Multiple iterations and on-site visits, continuous requirements analysis and feedback from end users to match users' needs and technical aspects of implementation
Impact	The intensive iterative process of requirement gathering and analysis in the beginning of the project led to a partial redesign of the AR In-Factory Platform as well as the addition of several features not initially planned
Recommendation	Dedicate time in the beginning to engage end users and to enable technology providers to better understand the end goal as well as explain to the end users the requirements of the technologies provided to make deployment easier
Gamification Platform	
Success	Platform agnostic gamification system with rule engine
Impact	A platform that performs equally well across more than one platforms
Recommendation	Discussion with administrator of platform for customized elements concerning the needs of each installation.
Human Resources re-adaptation engine	
Success	Development of an HR engine that uses heterogeneous information from multiple sources about tasks and employees and takes into account multiple criteria for decision making.
Impact	The HR engine developed can help the manager to make task assignment decisions according to the company's preferences.
Recommendation	The company's task assignment and scheduling policies have to be logged and incorporated into the HR engine in order to achieve the desirable results.
Incident detection engine (depth and thermal cameras)	
Success	On site visits, big collection of data and gaining knowledge on the legislation on occupation health and safety to match the shop floors' needs with respect to the workers.

Impact	Tools that can be helpful for the shop-floor and enhance safety conditions without insulting workers privacy.
Recommendation	Dedicate time at the beginning so that the applications meet the shop-floor needs but also respect the legislation and the workers.

5.1.2 FRAUNHOFER

Difficulties	
Title / Name	
Problem	Conflicting requirements for anonymous suggestions
Impact	The requirement initially collected during the first iterations with Sunlight specified that suggestions in the suggestion platform should remain anonymous in order to protect the workers privacy and make them feel comfortable, even when submitting more critical suggestions. Further tests with COMAU however, showed that for their use case the identity of a suggestions author is an important information, since they use a reward-system to motivate workers to submit their own thoughts.
Recommendation	In order to address these conflicting requirements, our solution consisted in externalizing this decision to the users themselves and tie them to a specific platform. So suggestions entered into the suggestions kiosk at the shop floor are always completely anonymous, suggestions submitted via Collaboration Platform however, are tied to a the Collaboration Platform user account, unless the user specifically chooses to make an anonymous suggestion.

Achievements	
Title / Name	
Success	Found a good way to motivate people without competition
Impact	It was requested that the handwashing game be not competitive among teams at the same factory. We found a way to offer a competitive gamification concept that however does not require competition among teams.
Recommendation	The “streaks” concept, i.e. competing against your own best result, proved valuable in both having game elements, but not comparing teams to each other.

5.1.3 EPFL

Difficulties	
Ontology Manager requirements	
Problem	Requirements gathering was carried out according to state-of-the-art practices, such as ORSD documents and NeON methodology, however, it was necessary to elaborate an ad-hoc strategy to better match the overall SatisFactory requirements.
Impact	The exploration of hybrid strategies for requirements definition has fueled the uncertainties regarding the subsequent Ontology Manager development stages
Recommendation	Set – at least – one intermediate iteration/deadline at the very early stage of the project to allow some reasonable adjustments.

Achievements	
SatisFactory OWL ontology from CIDEM xml schemas	
Success	The combined use of existing standards for industry data exchange and semantic web technologies paved the way towards the exploration of new approaches that further enrich the existing data management approaches.
Impact	The proposed solutions doesn't want to replace the existing IT ones but rather using those assets for new knowledge discovery and semantic data management.
Recommendation	At the early stages of the project, more effort should be dedicated to get a clear overview of the existing open source tools that use such enabling technologies, with particular emphasis on inference and reasoning engines.

5.1.4 ISMB

Difficulties	
Sensors selection	
Problem	Clarifications of environmental data to sense.
Impact	Commercial sensors allow different input range and sensibility. Wrong assumptions lead to duplicated work.
Recommendation	The sensor selection phase improves by defining the characteristics of produced data.

Network throughput	
Problem	Clarifications of the amount of environmental data to sense.
Impact	Device interfaces capabilities could not be enough to handle correctly the final data flows.
Recommendation	Select node and technologies accordingly to the required density.
Application requirements	
Problem	Clarifications of the main goal of the application.
Impact	Some of the selected parameters for the cognitive algorithm could introduce avoidable complexity.
Recommendation	Configure correctly the cognitive mechanism to accomplish the main goal by defining the right parameters and related weights.
Late adjustment	
Problem	Some requirements were communicated late.
Impact	Hastily carried activities are prone to mistakes.
Recommendation	Set a reasonable deadline for requirement adjustments.
Some end users' requirements were not feasible	
Problem	Some of the requirements from the end users resulted to be not feasible with the technology applied within the project.
Impact	Requirement has been marked as not implemented.
Recommendation	No specific recommendation has been made. It is normal to have this kind of requirements from not technology providing partners.

Achievements	
Hardware design	
Success	Requirement analysis lead to adequate hardware choices for the UWB-based wearable device.
Impact	Midway hardware modifications are less probable.
Recommendation	Requirement analysis can speed up design and development, so it's always a good practice to think through your next steps.
Components interconnection	
Success	Thanks to the UCs and scenarios, our components have been interconnected among themselves and tested in a real world scenario.
Impact	Creation of scenarios with strong synergies among components.
Recommendation	Positive feedback.

5.1.5 ABE

Difficulties	
DSS requirements	
Problem	It was necessary to elaborate more and clarify the response strategies alternatives.
Impact	The variation of the response strategies and the clarification of the procedures to be followed, based on the business objectives of the end users, influenced the rule engine of the iDSS component.
Recommendation	Set intermediary deadlines for refinement of requirements as a work in progress.

Achievements	
Shop floor Feedback Engine redefinition	
Success	Requirements analysis and continuous interaction with end users to elaborate on their needs and the partners' technical abilities.
Impact	The intensive iterative process of requirement gathering and analysis in the beginning of the project led to a partial redesign of the Shop floor Feedback Engine.
Recommendation	Dedicate time in the beginning to engage end users and to enable technology providers to better understand the end goal.

5.1.6 REGOLA

Difficulties	
Title / Name	
Problem	The requirements were at too high level.
Impact	Sometimes some confusion arose about their interpretation.
Recommendation	The requirements should be refined in more details.

Achievements	
Title / Name	
Success	JIRA was a good choice as a tool to collaborate in managing

	requirements
Impact	Easy way to track progress in the requirement gathering and to refer / track them in the following phase
Recommendation	Efforts to improve wide adoption of collaboration tools for requirements gathering and management could bring even more quality to such a delicate phase as requirements specification.
Title / Name	
Success	User case, BSC were effective in depicting the needs
Impact	N/A
Recommendation	N/A

5.1.7 GlassUp

Difficulties	
Unclear Requirements	
Problem	Some of the requirements were not clear or in contradiction
Impact	It has been difficult to choose the right feature to be implemented or to pick the right sensors or technologies
Recommendation	Validate the requirements since the beginning of the project and check them at different stages

Achievements	
Use Cases	
Success	Use Cases have offered the right suggestions to address hardware development
Impact	By taking into account how the device is going to be used allowed for the development of a useful device
Recommendation	Focus more on use cases analysis

5.2 DESIGN

5.2.1 CERTH

Difficulties	
Gamification Platform	
Problem	In administrator's user interface for Gamification, the process that should be followed in order to create a game was not clear apart from the developer of the platform
Impact	Every user that tried to create a game, needed to ask a lot about the steps that should be followed
Recommendation	A better design of the UI was made that guides the user around the UI in order to create every gamification element at the right time. Moreover, some tips are given while user is hovering over items with the mouse.
Gamification Platform	
Problem	The initial thought of teams was to be part of a game but it was a bit complicated
Impact	If a team was created to participate in more than one games, the administrator needed to create it again
Recommendation	Teams are designed independently of games so a team can participate in more than one games but be created only once.
Human Resources re-adaptation engine	
Problem	Re-adaptations of the work schedule that are generated by the engine had to be visualized properly.
Impact	Even though a feature-rich UI for the HR re-adaptation engine was not required, assigned tasks per each employee are shown in a Gantt graph in order to provide a straightforward view to the user.
Recommendation	The use of graphs can significantly improve the conception and comprehension of the user.
AR In-Factory Platform	
Problem	Dependency on multiple components (both software and hardware)
Impact	The dependency on multiple components meant that during the design phase, a lot of features were represented as black box elements pending the availability of actual implementation of these components to test interoperability, therefore creating uncertainty over the implementation specifics.
Recommendation	Better planning of availability of test versions of required components

	as soon as possible
AR In-Factory Platform	
Problem	Multi-platform support generated dependencies on libraries not existing on all platforms
Impact	Several components and functionalities had to be redesigned in order to either match availability of support for these features on all platforms or provide alternative methods to accomplish the same goals
Recommendation	When targeting multiple platforms, during the design phase conduct research on available code/libraries and OS capabilities of all the features to be supported on targeted platforms
AR In-Factory Platform	
Problem	UI design/Interaction couldn't be applied to all platforms in the same manner
Impact	The difference in capabilities and interaction methods of the supported platforms created different designs for the UI to the AR In-Factory platform
Recommendation	Test different UI/Interaction methods in emulators during the design
AR In-Factory Platform	
Problem	Each area might have different incidents of interest (eg collisions are of interest in an area with moving forklifts but not in a meeting room)
Impact	The algorithm was designed so that the detected incidents' categories are selected based on each area needs to avoid alerts of no interest
Recommendation	Design so that the detection can be adjusted to each area's needs
Training Analytics	
Problem	One type of visualization for analytics that was restrictive
Impact	The data are in various formats so the analytics where not very informative
Recommendation	Addition of various types of analytics in order to support every type of data as well as create more informative graphs

Achievements	
Gamification Platform	
Success	The gamified actions give points as it was meant to do in the beginning as well as badges, tangible objects and levels.
Impact	The gamified actions are more attractive
Recommendation	Provide a complete and motivating gamification strategy for

	supporting the appropriate actions
Gamification Platform	
Success	The gamification platform became an independent platform which can be adjusted to any function that the administrator wants to gamify
Impact	Flexibility, reuse and customization for every new instance of the platform
Recommendation	For every component that needs to be gamified an arrangement should be done with the administrator of the platform in order to manage the rules of the games correctly.
AR In-Factory Platform	
Success	Multiple platform support with minimal UI differences
Impact	The UI/Interaction was designed in such a way that required minimal inconsistencies between platforms making implementation easier
Recommendation	Test different UI/Interaction methods in emulators during the design
AR In-Factory Platform	
Success	Multiple AR Registration methods as plugins
Impact	The algorithms for AR target registration were designed so that they could be interchangeable from the Creation and Presentation tools making the authoring and deployment of the same training procedure to different platforms easy
Recommendation	Design from the beginning using a plugin methodology for components that are interchangeable
Human Resources re-adaptation engine	
Success	The HR engine is able to provide in a single view various information about the current status of tasks, employees and communication status with other SatisFactory components.
Impact	The user is aware of the new events that have been processed by the engine and their impact as well.
Recommendation	Automated handling and response to real-time events can potentially confuse the user, therefore the information presented has to be clear and comprehensive.
Training Analytics	
Success	Addition of extra information to the graphs
Impact	Facilitates the way data representation is done by providing more information about possible patterns, clusters and generally correlations
Recommendation	For deep understanding of data and possible knowledge extraction and reveal of hidden behaviors, the addition of information presented

	to graphs is necessary.

5.2.2 FRAUNHOFER

Difficulties	
Title / Name	
Problem	Basing the UI-palette on the project colors proved not suitable for industrial background
Impact	The first UI-designs for the suggestions platform relied heavily on the project color (orange) and adjacent colors on the color wheel (e.g. red). During usability tests with the industrial partners the choosen colors turned out to be not suitable for an industrial background where similar hues are assotiated with danger or warnings.
Recommendation	Based on these results the color palette was reevaluated leaving only few color accents in blue tones and using semaphore-colors only to appropiately indicate suggestions status. The takeaway from this issue being to always evaluate already defined colors carefully in the given context before chosing them as UI colors.

Achievements	
Title / Name	
Success	Good context analysis can correct mistakes early
Impact	The above problem was identified very early in the process, with the low-fidelity prototypes and when not much work had gone into the system. The problem could be fixed easily and with little cost.
Recommendation	Always test early with real users and in their real settings.

5.2.3 EPFL

Difficulties	
Ontology Manager design in practice	
Problem	As a result of the problem described above, the Ontology Manager design has been continuously updated even after the conclusion of T2.2. This was also due to the partial unavailability of relevant details concerning the application case scenarios.
Impact	The continuously developed design of this component was

	documented in the framework of D3.1. moreover, the unavailability of the above-mentioned info partially hinder the development phases described in the next sections
Recommendation	An initial checkup of the available/missing info together with the possibility of properly splitting the design phase reports from the implementation one, moreover, setting a final iteration of the former between M24 and M30 can be a good solution to address this matter.

Achievements	
SatisFactory Ontology hourglass-like shape design	
Success	The ontological model designed ad-hoc for SatisFactory has a hourglass-like shape whose level of generality decreases in both sides.
Impact	The particular design of the SatisFactory ontology support the semantics enrichment of the shop floor data flow in two ways: using terms of defined within the CIDEM, and using terms closer to the shop floor vocabularies.
Recommendation	No major recommendations

5.2.4 ISMB

Difficulties	
UI demonstrator mockup	
Problem	How to demonstrate the components functionalities.
Impact	Without defining ways to show the results, became harsh to demonstrate operational behavior.
Recommendation	In order to prove the validity of the mechanisms produced, it is necessary to define a base mockup about a UI for the demonstrator.
Error reaction	
Problem	How to detect wrong behaviors.
Impact	Without defining every point of failures, wrong behaviors became harsh to identify and handle.
Recommendation	Define all the point of failures.
Hardware design	
Problem	Hardware design was detached from end-user specific needs.
Impact	The first design was not immediately usable by end-users.

Recommendation	Discuss early design with the end-users.
RTOS	
Problem	RTOS was not always reliable.
Impact	Some of the issues encountered can be traced back to the chosen RTOS.
Recommendation	Check if some more reliable RTOS are available.
UWB infrastructure	
Problem	A UWB infrastructure has not been taken into account.
Impact	Using the same wearable sensor for the infrastructure led to a loss of precision and to a waste of components (BLE and IMU modules aren't needed for a UWB infrastructure)
Recommendation	Design a separate device for the UWB infrastructure.
Localization system approach	
Problem	According with the requirements, the localization system could have adopted a centralized approach.
Impact	Adopting a distributed approach led to higher effort.
Recommendation	Better evaluation of end-users needs.
Magnetometer	
Problem	The use of magnetometers is not reliable for industrial environments.
Impact	The presence of metals and machinery causes disturbances in the magnetic field that prevents correct use of the magnetometer.
Recommendation	Since the requested precision for localization is already met, do not use a magnetometer to improve it.
Issues related to component dependency	
Problem	Scenarios in which components are strictly related to each other have found some issues in the design phase due to different maturity of the applied technologies.
Impact	Delays in the realization of the scenarios. Integration post-activities have been difficult.
Recommendation	Step by step coordination of this scenarios should be sufficient to avoid the situation.

Achievements	
Set of commands	
Success	How to interact with sensor nodes.

Impact	By defining the ways to interact with sensors, the encapsulation and parsing of the messages became easier.
Recommendation	It is important to define the main targets and functions enabled by the infrastructure.
Design of secure communication channels	
Success	Development of components that exploit secure communication channels to communicate to each other.
Impact	The data exchanged and the privacy of the user are protected.
Recommendation	It is important, during the development of the components take in account the security and privacy aspects.
Hardware design	
Success	Hardware design has been completed in two phases.
Impact	First bigger design and subsequent miniaturization has proven to be a good viable way to proceed.
Recommendation	Foresee multiple iterations.
UWB	
Success	UWB technology resulted reliable for industrial environments.
Impact	UWB has proven to be a good technology to perform indoor localization in industrial environments with 20 cm precision.
Recommendation	UWB works in industrial environment only if there aren't metal surfaces in line of sight.
Persistent ecosystem	
Success	Thanks to the UCs and scenarios our components have been tailored in a standalone ecosystem.
Impact	Creation of end-to-end all ISMB components scenarios.
Recommendation	Useful for exploitation of multiple components from single partners.

5.2.5 ABE

Difficulties	
Issues related to component dependency	
Problem	Scenarios in which components are strictly related to each other have found some issues in the design phase due to different maturity of the applied technologies.
Impact	Delays in the realization of the scenarios. Integration post-activities

	have been difficult.
Recommendation	Step by step coordination of this scenarios should be sufficient to avoid the situation.
Connectivity availability	
Problem	WiFi connection was not available on the shopfloor
Impact	The transmission of data to the shopfloor and the feedback to the system required network connectivity. It was addressed at end user level for their specific use cases.
Recommendation	Consideration of such issues as early as possible.

Achievements	
Stand-alone and integrated solution	
Success	Parts of the solutions (Shopfloor Feedback Engine, Maintenance Toolkit, HR Workload balancing) can form groups that can be used as a standalone applications or integrated with other SatisFactory solutions
Impact	The ability to offer solutions as independent products or as parts of the complete SatisFactory solution facilitate exploitability.
Recommendation	Develop with exploitation alternative routes in mind.

5.2.6 REGOLA

Difficulties	
Title / Name	
Problem	Teleconferences and remote meetings are not the best ways to elaborate ideas jointly.
Impact	Some minor misunderstandings occurred, quickly fixed.
Recommendation	Having engineers and designers physically attending to focus groups or workshops could reduce misunderstandings and increase the capability to act and think as a team.

Achievements	
Title / Name	
Success	Distinguishing properly between skills required to carry out development activities and the ones needed for content management

Impact	Freeing resources, improving quality of service
Recommendation	When providing AR/VR services, it is important to have dedicated resources for 3D modeling

5.2.7 GlassUp

Difficulties	
Erogonomics	
Problem	Finding an ergonomic design for the Glasses has been very difficult
Impact	Many different designs have been tried
Recommendation	Focus more on ergonomics when designing a wearable device
Network Settings	
Problem	Network hard to set and debug
Impact	It takes a lot of time to successfully put Glasses in a network and to debug when there are problems
Recommendation	Develop a GUI or a Software to better set the network configuration
Log files	
Problem	Debugging problems on the Glasses is really difficult
Impact	When there is a problem on the Glasses it is hard to understand the real cause
Reccomendation	Make a more clear log file and give the possibility to get it from remote

Achievements	
Light Frame	
Success	The frame is very light
Impact	The user finds the frame very comfortable and light
Recommendation	Having an external box for the battery and network components helped in keeping the frame light
Safety-Oriented Design	
Success	The frame has been designed with the safety of the user in mind
Impact	The frame will be certified as safety glasses and the user consider it as such, still liking its design

Recommendation	Keeping safety as primary target made possible achieving this result

5.3 DEVELOPMENT

5.3.1 CERTH

Difficulties	
Social Collaboration Platform	
Problem	Reading historical data from CIDEM for visual analytics is very slow.
Impact	User experience suffers in Social Platform's dashboard view.
Recommendation	Take into account performance & speed when implementing services.
Gamification Platform	
Problem	Administrator's UI for gamification needed some functions that wasn't provided easily by the framework chosen for the implementation
Impact	A lot of time needed for some features to get implemented
Recommendation	Better design of UI based on what the framework can offer
Gamification Platform	
Problem	During development of the platform, new requirements arose that had to be integrated with the already implemented platform
Impact	Re-design of development that cost a bit in time
Recommendation	More clear and stable requirements for implementation as well as flexible coding in order to adapt to new needs.
AR In-Factory Platform	
Problem	Object Recognition System requires a very powerful GPU for the size of objects used in the pilots
Impact	This meant that the ORS had to be separated to a standalone server machine separate from the Presentation client and that in turn required a communication system to be developed between them and support for deployment of target definitions from Creation Tool to ORS server.
Recommendation	This was something that due to the nature of the algorithm could not be foreseen until development and testing on actual objects used in the use cases. As such, the only thing that could mitigate this would be the availability of testing material to be available early on but still this problem could arise further down the road. Therefore, best

	approach would be to iterate development and testing before actual deployment even in pre-pilot phase with actual objects used in the pilots
AR In-Factory Platform	
Problem	Initial API specifications of dependent components and external libraries changed during development
Impact	The changes in APIs meant re-development of elements of the AR In-Factory platform that were using them
Recommendation	Don't change API specs agreed during design. If required, add the new functionalities to new functions/libraries that complement the initial API, in order to minimize disruption
Incident detection engine	
Problem	Need for fast algorithms since image processing can be time consuming
Impact	Threaded algorithms to meet the applications' needs
Recommendation	Take into account performance and speed
Human Resources re-adaptation engine	
Problem	The configuration of the HR engine in order to operate in each specific shop floor can be time consuming due to different requirements.
Impact	Improper configuration of input parameters can lead to undesirable output.
Recommendation	Certain parts of the source code must be generic in order to cover all possible cases. A change can be implemented with the minimum possible effort.
Human Resources re-adaptation engine	
Problem	In some cases, one or a number of the sources that are used as input by the engine may not be available.
Impact	In such a case the HR engine must be able to operate using the available information only as input, if possible. Thus, different actions can be performed based on the available information.
Recommendation	The system has to be developed in a way that it can ignore missing input which is not critical.

Achievements	
Social Collaboration Platform	
Success	AR glasses only support RTSP for streaming, which is not supported by browsers, thus not suited for the Social platform web app. Stream

	conversion applied to resolve the problem.
Impact	Using third-party libraries with flaws and limited functionality to convert streams. Extra code and effort to make everything work. Potential bugs introduced into the software.
Recommendation	Consider software technologies when choosing devices/protocols.
Social Collaboration Platform	
Success	Browsers hosting the Social platform front-end require https for use of certain resources such as the microphone, forcing the whole app and remote resources (other SatisFactory apps displayed in the Social platform), to use https. Https is impossible to properly setup in a non-internet environment, so it was applied to microphone-specific UI only, using pop-up window and self-signed certificate.
Impact	Sub-optimal UI for the functionality of talking to the wearer of the AR glasses from the Social platform.
Recommendation	Get SSL certificates for server machines.
AR In-Factory Platform	
Success	Support for platforms not initially planned. Incorporation of features above and beyond initial planning into the AR In-Factory Platform
Impact	The development of the AR In-Factory Platform resulted in a combination of Creation tool and Presentation tool that cover Windows, Android, Hololens and GlassUp platforms as well as provide support for Remote Assistance, Notifications and Gamification through the same application and control of the application using hands-free gestures
Recommendation	Choose the development platform wisely. Our choice of Unity made cross-platform development easy and the addition of features a simple case of building a Unity add-on library to support each desired feature
Human Resources re-adaptation engine	
Success	The HR engine allows the user to configure the parameters that affect the tasks assignment process, such as the weights used in the computations.
Impact	Adaptation in calculations on demand increases the flexibility of the engine in certain conditions.
Recommendation	As initial requirements may change over time, the system has to provide the user with the ability to alter certain parameters regarding the computations that are performed by the engine.
Human Resources re-adaptation engine	
Success	The HR engine can operate in offline mode (simulation) as well.

Impact	Offline mode proved to be useful for assessing the output of the HR engine in certain conditions that are difficult to be observed in real-time mode.
Recommendation	Offline operation should be considered in cases when there are many factors that can affect the output.

5.3.2 FRAUNHOFER

Difficulties	
Title / Name	
Problem	XML storage issues
Impact	Initially it was planned to store data from the suggestions platform and the gamification framework using the CIDEM schema used by other project components. However for simple data structures used by a single application, like it is the case for the suggestions platform, the work exceedes the benefit.
Recommendation	We dismissed the XML storage for simple structures like suggestions and some parts of gamification, but in order to keep global data in the project repository we additionally performed regular exports to CIDEM.
Title / Name	
Problem	Ionic versioning
Impact	The Ionic Framework used for the suggestions kiosk provides an excellent way to create small mobile applications based on web technologies such as HTML5, CSS3 and Javascript. However the versioning represents a problem here: Ionic, similar to the AngularJS framework it is based on, has very divergent versions and updating an Ionic application is a more complex task. When development started the stable Ionic version was Ionic1, which during the curse of the project has changed to Ionic3.
Recommendation	Since updating the application would have resulted in unplanned work efforts exceeding the personnel budget, we stayed with Ionic1.

Difficulties	
Title / Name	
Problem	Ionic framework limitations
Impact	Another Ionic issue is the limited access to native functionalities. This is better for newer versions, but since upgrading an application was

	out of scope (see above) we faced all the limitations tied to the first Ionic version.
Recommendation	When developing applications with a bigger need for native mobile functionalities this definitely should be taken into account.
Title / Name	
Problem	Internationalization
Impact	Deployment at the industrial pilots required for the suggestions platform to be available in the local language. Often in such cases a language switch is incorporated, so users can adapt the interface language. In case of the suggestions platform, an interface partly filled with user-generated content, a language switch would have led to an interface populated in different languages, which is much more difficult to use and therefore not recommended.
Recommendation	We opted to define the language when installing, so the local language will be chosen and all subsequently added content will be in said language.

5.3.3 EPFL

Difficulties	
SatisFactory Ontology (SFO)	
Problem	The SFO may be perceived as a growing asset that evolved together with the development of the SatisFactory ecosystem.
Impact	As an emerging technology, many aspects regarding the use of semantics have been reasonably changing along the last 35 months.
Recommendation	The design phase should be split from the implementation one, therefore, the deadline of T3.1 might be extended to M28 or M30.

Achievements	
Ontology as a data management tool	
Success	There is an increasing interest in ontology-based solutions for the industry
Impact	The practitioners in this field are refining both designing and developing strategies as an attempt to find a good compromise between the ontological correctness and the practical data management aim of the proposed model.
Recommendation	More time should be spent in refining the definitions given to each

	term and the proper axiomatization of the

5.3.4 ISMB

Difficulties	
Integration of third party software	
Problem	How to use third party not mature open source software
Impact	It is difficult to exploit because the software is not well documented and not completed
Recommendation	When possible, try to use open source software of projects currently maintained, with a good documentation and with a large community of developers.
Embedded drivers	
Problem	Absence of USB serial drivers in the developed firmware.
Impact	Data exchange is possible only through BLE.
Recommendation	Improve firmware with USB-CDT capabilities.
Multi-Threading	
Problem	Complex multi-threading to receive data from multiple sensors simultaneously has not been fully developed.
Impact	Wearable device cannot run inertial sensors and UWB at once.
Recommendation	Evaluate RTOS capabilities for each task to ensure desired behavior.
Large scale deployment (UWB)	
Problem	To accomplish large scale deployment, a more complex localization system is required.
Impact	With the current set up, only four devices can be localized at a time.
Recommendation	Develop a different set up to increase localization capabilities and the area covered by localization.
Missing information from partners specifications	
Problem	Interactions among components have been very difficult to implement due to the lack of coordination of technical details due to insufficient communication across implementation tasks.
Impact	Interactions among components have been reduced.
Recommendation	Planning and coordination should be enough to sort this out. Iterative approach and fixed release time for iterative testing should be implemented. A server lab to test deployments would be also a nice

	to have.

Achievements	
Component Emulation Framework	
Success	Development of tools to emulate complex or external components.
Impact	Improvement given by the parallelization of the development process as well as the ability to test the components.
Recommendation	It is important to share these tools in order to test and compare the interaction between components.
Energy saving	
Success	Exploits the user button to set the device in STOP mode.
Impact	Battery lasts longer when the device is not used.
Recommendation	By developing different hardware configuration, the power consumption of the devices could be still reduced.
Cutting edge technologies applied in development	
Success	In the development phase cutting edge technologies have been adopted at high TRLs.
Impact	High TRLs with cutting edge technologies.
Recommendation	High TRL requirement for components is positive.

5.3.5 ABE

Difficulties	
Integration of third party software	
Problem	How to use third party not mature open source software
Impact	It is difficult to exploit because the software is not well documented and not completed
Recommendation	When possible, try to use open source software of projects currently maintained, with a good documentation and with a large community of developers.
Integration with other components	
Problem	Integration with multiple components did not get the required level of attention in the initial phases.
Impact	More effort was required in the deployment phase.

Recommendation	Dedicate efforts for setting rules for integration interfaces with the final (or close to final) route of implementation in mind.

Achievements	
HR Workload Balancing features	
Success	Complete tool operational as a result of smooth collaboration between partners.
Impact	HR Workload Balancing offers the ability for automated scheduling considering the available tasks at a given point and for re-scheduling when a new task occurs.
Recommendation	Clear vision from the beginning and hand in hand co-operation between the partners involved in the task through its lifetime and in the testing period.

5.3.6 REGOLA

Difficulties	
Title / Name	
Problem	Issues compatibilities between .Net third party libraries compiled with updated .Net framework and Unity
Impact	Time has been spent for debug and fixes
Recommendation	No specific recommendation. Issue depends heavily on the software marketplace
Title / Name	
Problem	Local databases
Impact	Designed could had be addressed from start on a more commercial oriented IT infrastructure.
Recommendation	Cloud database resources project wide available

5.3.7 GlassUp

Difficulties	
SOM	
Problem	The SOM chosen as electronic main board was already going in end

	of life phase
Impact	The supplier of the SOM is giving limited technical support
Recommendation	When choosing a technology, be sure that the component has an extended lifetime to guarantee proper support
Operating System	
Problem	The operating system working on the device is quite old
Impact	Third-party softwares only work on newer Oss
Recommendation	Always working on up-to-date Oss to ensure using bug-free external libraries

Achievements	
AR Glasses	
Success	Fully function AR Glasses
Impact	The device offers a true AR See-Through experience that can be easily integrated with existing softwares
Recommendation	Have clear targets in mind when developing a new device and ask for feedbacks to end uses
Battery Life	
Success	The device can last in certain conditions up to a full shift
Impact	It is very important for an industrial device to have a good battery life to avoid to change battery during an important procedure
Recommendation	Carefully evaluate energy consumption for all electronic components and choose the battery accordingly

5.4 TESTING

5.4.1 CERTH

Difficulties	
Gamification Platform	
Problem	Gamification giving errors on calculating points
Impact	Players getting more or less points than the denoted ones in rules
Recommendation	Testing in more detail the code that computes points

Gamification Platform	
Problem	Rules weren't updated correctly because of tables that saved rules with awards
Impact	Changes in rules concluded in rules that wouldn't give awards
Recommendation	Update all correlated tables with new information about the rule
AR In-Factory Platform	
Problem	Remote access to pilot sites unavailable
Impact	The inability to remotely test components and software installed at pilot sites due to pilot sites' restrictive network access from external locations meant that parts of the testing were carried out 'blindly' to the real circumstances
Recommendation	Pilot sites should make access to local installations easier for technology providers
AR In-Factory Platform	
Problem	Differences between development environment and pilots'.
Impact	Some bugs and interconnectivity issues cannot be foreseen before testing at the real pilot site due to differences in hardware used, network deployments etc..
Recommendation	Perform more tests in environments similar to the pilot.
AR In-Factory Platform	
Problem	Modification of shop-floor equipment/assembly lines after initial development
Impact	The change in locations/equipment etc. in the pilot sites after the initial development of software components/training scenarios etc. meant partial re-development of tools and training procedures to match the changes
Recommendation	Pilot sites should notify technology providers early on prospective changes that may impact development/testing
Human Resources re-adaptation engine	
Problem	The detection and correction of flaws in calculations during the development phase.
Impact	Due to the number of computations and their dependencies, a flaw which affects the final result can be missed. Logging of intermediate results to a log file has been implemented.
Recommendation	Detailed logging of all critical operations is important for detecting possible flaws easily.
Incident detection engine using thermal cameras	

Problem	Weather temperature that changes during the year can lead to a big variety of relative differences between the batteries and the surroundings temperature.
Impact	The aforementioned situation can lead to false alarms caused by human presence during cold months
Recommendation	An extra part detecting humans from movement was added
Incident detection engine using depth cameras	
Problem	Highly reflecting floors restricted the area under monitoring
Impact	Changes to the raw data processing helped to increase the monitoring area
Recommendation	Good inspection of the monitoring area's particularities

Achievements	
AR In-Factory Platform	
Success	Pre-pilot tests at CPERI
Impact	The pre-pilot testing revealed potential pitfalls to avoid during the pilot phase and made pilot deployment smoother
Recommendation	Inclusion of an Industrial Lab or a simulated environment, before going on to the final pilots.
Human Resources re-adaptation engine	
Success	Pre-pilot tests that were performed at CPERI helped to reveal implementation Difficulties that were corrected successfully.
Impact	The HR engine was ready to be deployed to the pilots after the tests that were performed at CPERI.
Recommendation	Testing the component and its integration to the system in a pre-pilot environment is necessary.

5.4.2 FRAUNHOFER

Difficulties	
Title / Name	
Problem	Access to servers in limited-access environments
Impact	We could not access installations of our software at COMAU, due to the refusal of the IT department to provide a remote connection option. This made testing and corrections very difficult.

Recommendation	Clarify at the beginning of the project that remote access rights will be granted.

Achievements	
Title / Name	
Success	Continuous integration and automated tests for finding mistakes
Impact	The use of continuous integration is crucial, especially for finding dependency mistakes between developer's machines and server environments. Automated testing also resulted in the elimination of bugs long before they could be deployed on the real servers.
Recommendation	Always perform CI and automated tests before accepting a development commit.

5.4.3 EPFL

Difficulties	
Knowledge modelling for human resource optimization and analysis of dynamically evolving shop floor operations	
Problem	According to the project work plan, the support for human resource optimization should have tested by the end of M18 while the analysis of dynamically evolving shop floor operations at the end of M20 despite shop floor data have been made available after that deadline.
Impact	Differences between development environment and pilots. Moreover, testing results have been limited. Some bugs couldn't be foreseen before deploying the real pilot.
Recommendation	More attention on the testing phase which can be a critical phase for a succeeding deployment of a background component such as the SatisFactory Semantic Framework.

Achievements	
Human Resource Optimization through Semantically-Enriched Data	
Success	The above-mentioned IJPR publication will be available by the end of 2017.
Impact	As an academic partner of the SatisFactory consortium, publishing represents an important exploitation and dissemination result. This was accomplished thanks to the intense and efficient collaboration

	among the partners.
Recommendation	One industrial case has been presented, however, the inclusion of two more case would have represented a big added walue to this publication.

5.4.4 ISMB

Difficulties	
Scalability Framework	
Problem	How to test the distributed components interaction.
Impact	Reliability of devices on the final deployment increase if exploit dedicated software to emulate those devices.
Recommendation	Development of dedicated software components to emulate large scale distributed interactions.
Simulators	
Problem	How to test the components behavior.
Impact	The development and test of multiple running devices became easier if anticipated by simulated analysis.
Recommendation	Perform the simulator selection accordingly on the node and technology of interest.
Test site	
Problem	Differences between development environment and pilots'.
Impact	Some bugs cannot be foreseen before deploying the real pilot.
Recommendation	Perform more tests in environments similar to the pilot.
Bug fixing	
Problem	Some of the bugs are harsh to identify.
Impact	The system run correctly and then suddenly crashes.
Recommendation	Use watchdogs to restore the system after crashes.

Achievements	
Sniffing Tools	
Success	Analyze runtime network communications.
Impact	The bug fixing process improve due to a better localization of the runtime issue.

Recommendation	Exploit existing tools to capture runtime communications.
Log mechanisms	
Success	Analyze runtime components behavior.
Impact	The bug fixing process improve due to a better characterization of the runtime issue.
Recommendation	Exploit tools to store runtime information.
Bugs handling	
Success	All the bugs found during the tests have been addressed and handled.
Impact	The system is able to recover to a stable state.
Recommendation	Try to fix these bugs without restarting the whole system.
Missing a testbed outside pilots	
Problem	Developers have highlighted the lack of a server dedicated to testing implementations before deployment. The only small scale pilot was a pilot itself and remote accessing for testing has been more difficult than a simple software environment.
Impact	Testing environment created at our premises.
Recommendation	A common testing environment should be implemented and maintained.

5.4.5 ABE

Difficulties	
Test site	
Problem	Differences between development environment and pilots'.
Impact	Some bugs cannot be foreseen before deploying the real pilot.
Recommendation	Perform more tests in environments similar to the pilot.

Achievements	
Industrial Lab involvement	
Success	The involvement of an "experienced" end user like the Industrial Lab of CERTH/CPERI.
Impact	It was possible to clear out a lot of issues/bugs at the Industrial Lab before going to the Industrial Pilot end users; SUNLIGHT and

	COMAU.
Recommendation	Inclusion of an Industrial Lab or a simulated environment, before going on to the final pilots.

5.4.6 REGOLA

Difficulties	
Title / Name	
Problem	Different setup between different IT infrastructures and end user IT policies in the shopfloor.
Impact	Significant impact in terms of time spent fixing issues related to security policies in the shopfloor
Recommendation	To setup specific test sandboxes where testing could occur free from constraints related to the networking policies

Achievements	
Title / Name	
Success	Testing dedicated team
Impact	Better software quality
Recommendation	Always use in testing people different from the developers who made the software.

5.4.7 GlassUp

Difficulties	
Frame Reliability	
Problem	The frame was not always reliable when applied in an industrial environment
Impact	Breaking of some parts of the Glasses happened during tests
Recommendation	When designing a device for industrial environment, take into account it is a difficult environment where to operate

Achievements
Device Robustness

Success	All bugs and problems experienced during the testing have been addressed
Impact	The device is robust and stable for industrial use
Recommendation	Try to resolve all problems before deployment

5.5 DEPLOYMENT

5.5.1 CERTH

Difficulties	
Social Collaboration Platform	
Problem	Already occupied port for the server
Impact	The webpage could not load
Recommendation	Choose one dedicated port for the webpage
Social Collaboration Platform	
Problem	Soap dispensers were not cooperating with Social Platform correctly because the calls had specific parameters that should be saved in database
Impact	Soap dispensers were used daily but points were not saved for the teams
Recommendation	Clarification of parameters in order to sync the cooperating systems
AR In-Factory Platform	
Problem	Difference of conditions for deployment at different pilot sites.
Impact	Necessity to solve ad-hock issues at different pilot sites.
Recommendation	Try to unify requirements for deployment, while respecting company policies of the end users.
AR In-Factory Platform	
Problem	Lack of WiFi Networking at pilot sites, restrictive IP handling, not allowing static IP addresses
Impact	The networking issues made troubleshooting difficult and created unforeseen issues, e.g. devices not keeping a necessarily known IP
Recommendation	Provide technology providers with easy means to deploy solutions reliant on wireless networking and compartmentalize your network so that different systems can work under different network rules

Human Resources re-adaptation engine	
Problem	The operation of the HR engine mainly depends on the CIDEM, iDSS and the middleware. These components must be configured properly and already started beforehand.
Impact	The HR engine cannot receive the input required in case any of the components mentioned above is not available.
Recommendation	Check all the dependencies before running the HR engine component.

Achievements	
AR In-Factory Platform	
Success	Access to certain end users' shop floors with use of remote control tools.
Impact	Easier and faster deployment of updates and debugging.
Recommendation	Try to define as early as possible resources and locations where it can be allowed to offer remote access and control.
AR In-Factory Platform	
Success	Deployment of unplanned features and deployment platforms
Impact	Expansion of the scope of the AR in-Factory platform to more use cases and users
Recommendation	Follow the technology trends along with the end users during the timeframe of the project and identify potential advancements not predefined in the DoW
Social Collaboration Platform	
Success	Same as with AR platform - Access to certain end users' shop floors with use of remote control tools.
Impact	Easier and faster deployment of updates and debugging.
Recommendation	Try to define as early as possible resources and locations where it can be allowed to offer remote access and control.
Human Resources re-adaptation engine	
Success	The HR engine can be easily deployed, as it is a portable application which does not require a special installation procedure.
Impact	The HR engine can be deployed in short time and can be updated to a newer version easily.
Recommendation	Try to pack all the dependencies of the application into a single place
Incident detection engine (depth and thermal cameras)	

Success	Same as other tools - Access to certain end users' shop floors with use of remote control tools.
Impact	Easier and faster deployment of updates and debugging.
Recommendation	Try to define as early as possible resources and locations where it can be allowed to offer remote access and control.

5.5.2 FRAUNHOFER

Difficulties	
Title / Name	
Problem	Configuration Management
Impact	Services are orchestrated with central configuration management, but this is cumbersome to configure.
Recommendation	Use sophisticated tool for configuration management
Title / Name	
Problem	Lack of proper deployment strategy
Impact	Services needs to be manually installed and configured.
Recommendation	Use a deployment model for shop floor
Title / Name	
Problem	Server configuration
Impact	The suggestions platform pulls its information from an REST-API. At first the server data was encoded in the apps internal configurations, but practice showed that depending on the deployment environment the server address is prone to frequent changes, which always led to a reconfiguring ane recompiling of the mobile application.
Recommendation	To avoid this problem a settings page was created in order to allow adminstration users to dinamically adapt the server address in order to suit the local configuration.

Achievements	
Title / Name	
Success	Remote deployment
Impact	Because of limited time and human ressources, deployment was always an issue. We could not always personally deploy at the

	industrial demonstrators.
Recommendation	With the help of partners and well written documentation the difficulties were avoided.

5.5.3 EPFL

Difficulties	
	OSF-based Satisfactory Semantic Framework
Problem	Different conditions for deployment at different pilot sites
Impact	Delayed deployment due to diverse conditions that have not been foreseen at early stage.
Recommendation	Better understating on the deployment conditions for each of the shop floor, which may be reasonably different

Achievements	
	OSF-based Satisfactory Semantic Framework
Success	The use of Open Semantic Framework (OSF) as a means for deploying the Ontology Manager helped the former to debug some issues encountered while using it.
Impact	Fostering and supporting the development of open-source software for knowledge management.
Recommendation	A clear view of the selected software's limitations, may avoid eventual deployment delay.

5.5.4 ISMB

Difficulties	
	Boot parameter optimization
Problem	Default application parameter optimization on real scenario.
Impact	The starting values are not adaptive in the specific environmental context where the infrastructure is deployed.
Recommendation	By introducing an early phase during boot that analyze and configure the starting parameters, main behavior is improved.

Deployment of code in production	
Problem	Setup of the runtime environment in production.
Impact	Code produced in laboratory needs specific configuration settings that must be reproduced in the production system.
Recommendation	Store all the settings required. If possible use containerized solutions like Docker.
HW supply and network environment	
Problem	All testing has been done with a “bring your own device” approach from the technology providing partners’ perspective. Network connection and support have been not adequate in many circumstances.
Impact	Delays and a lot of effort required.
Recommendation	Better coordination of deployment activities.
One and only device to host many components	
Problem	In some occasions we found other partners SW installed and conflicting with our SW components, in the HW we have provided. End users have granted remote access to our HW and SW to projects’ partners without our consent.
Impact	Wasted time in troubleshooting.
Recommendation	Administrative rights should not be granted to end users.

Achievements	
Device remote control	
Success	The ability to control remotely some devices.
Impact	It allows better verifying and eventually fixing deployment issues.
Recommendation	Define secure way to access these remote devices.
Improved system	
Success	System has been improved thanks to the problems addressed in deployment and to end-users’ suggestions.
Impact	The system now considers more environmental aspects.
Recommendation	Take into account end-users’ suggestions.
Real world manufacturing environment approach	
Success	A real world manufacturing environment has embraced our components.
sssImpact	On site pilot testing.

Recommendation	Heterogeneous pilots provide positive feedback.

5.5.5 ABE

Difficulties	
Deployment at different pilot sites	
Problem	Difference of conditions for deployment at different pilot sites.
Impact	Necessity to solve ad-hock issues at different pilot sites.
Recommendation	Try to unify requirements for deployment, while respecting company policies of the end users.

Achievements	
Real world remote access	
Success	Access to certain end users' shop floors with use of remote control tools.
Impact	Easier and faster deployment of updates and debugging.
Recommendation	Try to define as early as possible resources and locations where it can be allowed to offer remote access and control.

5.5.6 REGOLA

Difficulties	
Title / Name	
Problem	Same issue reported for testing impacted on deployment phase too: different setup between end user IT infrastructures/policies and technology provider partners. Wi-fi connections were an issue.
Impact	Significant impact in terms of time spent fixing issues.
Recommendation	To setup specific test sandboxes where testing could occur free from constraints related to the networking policies

Achievements	
Title / Name	
Success	Using IIS as mean to distribute procedure bundles were cumbersome

Impact	Added complexity to the installation and the setup
Recommendation	Windows services greatly simplified the installation procedure

5.5.7 GlassUp

Difficulties	
Wifi Network	
Problem	In an industrial environment there are many different wifi settings
Impact	Not always easy to connect the Glasses to the wifi network of the shop floor
Recommendation	Have an easy way to connect the device and to debug where there are problems
Remote Assistance	
Problem	During deployment it has been difficult to offer assistance remotely
Impact	Lot of time lost to successfully deploy the device in the shop floor
Recommendation	Create best practice and short guides to help technical teams in the deployment phase

Achievements	
Better device after deployment	
Success	The feedback received from end users' shop floor led to a better device
Impact	The device has been improved from an ergonomic and functional point of view
Recommendation	Take into account every data collected from real use of the device

5.6 MAINTENANCE

5.6.1 CERTH

Difficulties	
Social Collaboration Platform	
Problem	A user of Social Platform has forgotten the password
Impact	There wasn't a way of recovering so he was deleted from database with all the associated records being deleted too.
Recommendation	Implementation of "Forgot password?" feature
Social Collaboration Platform	
Problem	Social collaboration runs on a server that consumes 2GB of RAM. Ram runs out if many applications consumes a lot of it and the server needs to restart
Impact	Some data may be lost
Recommendation	Install the server of the platform on a PC with at least 3 GB available RAM
Social Collaboration Platform	
Problem	Bugs that were revealed after deployment, when actual users starting testing the platform
Impact	Daily resolution of bugs that needed new deployments of versions remotely
Recommendation	Provide more time interval for testing phase before installing the software to pilots
AR In-Factory Platform	
Problem	Bugs and unforeseen behaviors manifested themselves only in the pilot sites.
Impact	It is more difficult to solve bugs remotely with limited connectivity.
Recommendation	Try to do some tests in pilot similar environments or provide better remote maintenance support to technology providers
AR In-Factory Platform	
Problem	Changes by pilot sites to UC parameters after deployment
Impact	Re-authoring of AR training procedures
Recommendation	Keep changes to training scenarios early in the development phase
Human Resources re-adaptation engine	

Problem	New categories of employees or tasks have to be added to the system in the future.
Impact	HR engine has to be updated to support new functionalities.
Recommendation	Design the component by taking into account possible changes that may occur, in order to reduce the impact.

Achievements	
AR In-Factory Platform	
Success	Maintenance of the components after their deployment in the pilots
Impact	The AR tools have been constantly monitored and updated remotely, also after their deployment in the pilot sites.
Recommendation	When the software is deployed, remember to provide backup versions of the software and hardware components and already consider how these can be maintained remotely
AR In-Factory Platform	
Success	End users were able to troubleshoot some issues without the need for physical presence or remote maintenance by the technology providers
Impact	The ability to solve issues by on-site personnel lessened maintenance efforts by the technology providers
Recommendation	Provide detailed instructions on installation, configuration and maintenance of components to end users. Most problems are easier to solve by on-site personnel than remotely.
Incident detection engine (depth and thermal cameras)	
Success	Maintenance of the components after their deployment in the pilots
Impact	The incident detection engine has been constantly monitored and updated remotely, also after their deployment in the pilot sites.
Recommendation	Camera installation at places protected by human presence or other factors that may harm or move the cameras and need recalibration

5.6.2 FRAUNHOFER

Difficulties	
Title / Name	
Problem	Central logging monitoring is difficult

Impact	Inspection of Individual service logs is difficult, mostly due to log verbosity.
Recommendation	Employ a proper monitoring infrastructure and health check mechanism

5.6.3 ISMB

Difficulties	
Runtime log control	
Problem	Developers do runtime log control manually.
Impact	The risks of miss data errors are high.
Recommendation	Develop scripts that performs autonomous parsing and highlights errors.
Runtime fault detection	
Problem	Developers do fault detection of a link manually.
Impact	The risk of miss link errors grows drastically with the amount of data produced.
Recommendation	Develop scripts that perform runtime autonomous monitoring and highlights faults.
Training	
Problem	Training for the persons in charge of pilots was not anticipated.
Impact	Unforeseen effort was spent to teach them how the system works.
Recommendation	Consider the effort needed for training.
Bugs	
Problem	Some bugs manifested themselves only in the pilot site.
Impact	It is more difficult to solve bugs remotely.
Recommendation	Try to do some tests in pilot similar environments.
Unplanned update and last minute changes	
Problem	Some changes have been rolled out without the required scheduling and information to affected partners.
Impact	Broken pilots demonstrations and required fixes after troubleshooting.
Recommendation	Planning deployments is vital in these situations, in order to avoid miscommunication.

Achievements	
Runtime signaling	
Success	Every device involved is autonomously able to signal information at runtime.
Impact	The behavior analysis is easier due to colored lights emissions produced by LEDs.
Recommendation	It is important to define a legend about the signaling method chosen to support the runtime analysis.
Remote Maintenance of the components	
Success	Maintenance of the components after their deployment in the pilots.
Impact	The software has been monitored and restored remotely, also after its deployment in the pilot sites.
Recommendation	When the software is deployed, remember to provide backup versions of the software and hardware components and already consider how these can be maintained remotely.

5.6.4 ABE

Difficulties	
Bugs	
Problem	Some bugs manifested themselves only in the pilot site.
Impact	It is more difficult to solve bugs remotely.
Recommendation	Try to do some tests in pilot similar environments.

Achievements	
Remote Maintenance of the components	
Success	Maintenance of the components after their deployment in the pilots.
Impact	The software has been monitored and restored remotely, also after its deployment in the pilot sites.
Recommendation	When the software is deployed, remember to provide backup versions of the software and hardware components and already consider how these can be maintained remotely.
Maintainability is connected with exploitation potential	
Success	The setup of certain components had the dimension of maintainability embedded earlier, when the exploitation potential

	was more prominent.
Impact	Maintainability in a straight forward and easy way.
Recommendation	Consideration of the exploitation potential as a boosting mechanism for all stages, including maintenance.

5.6.5 REGOLA

Difficulties	
Title / Name	
Problem	Same issue reported for testing impacted on maintenance too.
Impact	Severe restrictions applied by end the user IT policies made difficult or impossible to provide effective remote assistance. Impact was not too severe because it was possible to provide physical support by means of missions in the end user shop floor but consequences could have been significant were the physical distance between partners greater.
Recommendation	To allow means to provide remote assistance and make it effective.

5.6.6 GlassUp

Difficulties	
Debug Device	
Problem	When device is not working it is difficult to find the real problem
Impact	Debugging the device requires high computer science skills and the bug resolutions is not easy
Recommendation	Have an easy way for non-technical people to debug errors or problems on the device

Achievements	
Remote Firmware Update	
Success	Easy way to update the firmware remotely
Impact	When there is a software problem it is easy to remotely update the firmware
Recommendation	A procedure for remote update is desirable to help the maintenance

of the device

CONCLUSIONS

This deliverable aims to present the results of the SatisFactory's platform evaluation. The platform was evaluated at COMAU's and SUNLIGHT's premises as well as at CERTH/CPERI. The results first of all remark the projects success from the aspect both of workers and decision makers. The evaluation of the Satisfactory system had specific objectives and was based on a methodological framework, developed in deliverable D5.2. The conclusions of the evaluation process are listed as per three different aspects based on (i) SUS, (ii) SatisFactory evaluation criteria and (iii) exploitable products.

The responses in every aspect were positive and the continues improvement of the SatisFactory platform is reflected on the scores. The second evaluation session had better results than the first in all pilots. Additionally, both pilots had better results than the pre-pilot.

Moreover, the developers of the components report their difficulties and achievements from their involvement in the SatisFactory project. The reported difficulties and achievements may be useful to future projects. Finally, this deliverable is oriented also to potential customers since it provides information and conclusions from the end users of SatisFactory platform.

REFERENCES

[1]. Bangor A., Kortum P. and Miller J., Determining What Individual SUS Scores Mean: Adding an Adjective Rating Scale, Journal of Usability Studies, 4(3): pp 114-123, 2009.
[2]. Bangor, A., Kortum, P., and Miller, J.A., The System Usability Scale (SUS): An Empirical Evaluation, International Journal of Human-Computer Interaction, 24(6): pp.574-594, 2008.
[3]. Brooke, J. SUS-A quick and dirty usability scale. Usability Evaluation in Industry, pp. 189-194, 1996.