Ecosystem for COllaborative Manufacturing PrOceSses – Intra- and Interfactory Integration and AutomaTION
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Index:

1 Executive Summary

The objective of *Task 8.4 Evaluation According to Specification* is to measure the outcome of the project against the user requirements with specific focus on stakeholder feedback captured in the analysis of the use cases.

Test cases for the pilots have been run to verify and measure the level of adherence of the behaviours of the COMPOSITION Integrated Information Management System and Decision Support tools with the requirements identified in WP2 and the Key Performance Indicators (KPIs) as defined in the Description of Action.

This report covers the last three steps of the evaluation plan described in *D8.7 Evaluation Framework*: Gather Evidence, Analyse Results and Report Findings, leveraging on selected results from *D8.4 Supply Chain Pilot II* and *D8.6 Value Chain Pilot II*.

1.1 Requirements Engineering

Twenty-two Lessons Learned have been reported in the final development cycle. Because of the high-level nature of most of the COMPOSITION requirements, the Lessons Learned generally have affected their implementation more than their substance.

At the time of writing, 61 requirements have been implemented and validated by the end users, 2 are still under implementation and 63 requirements have been implemented. These implemented requirements are typically quite technical in nature, and end user validation is not applicable.

1.2 Evolution of Use Cases

Throughout the duration of the project, the specification of the COMPOSITION use cases underwent a continuous (re-)assessment and refinement, from the first iteration reported in *D2.1 Industrial Use Cases for an Integrated Information Management System* to the final list containing the implemented five very-high-priority use cases, five high-priority use cases and two Business Model subcases. An additional six medium-priority uses cases were not implemented.

The process was inspired by British Design Council's 'Double Diamond' design process model, and further encouraged by the reviewers at the M18 Review, recommending to keep focus on those use cases that are most relevant and promise most added value from a technology, impact and exploitability point of view.

1.3 Pilot Sites and Use Cases

Five intrafactory use cases (marked with asterisks* in the lists below) and four interfactory use cases have been implemented as follows:

At **Boston Scientific Ltd.** in Clonmel, Ireland, one very-high-priority use case and two high-priority use cases were implemented, the last one as concept only:

- UC-BSL-2 Predictive Maintenance*
- UC-BSL-3 Asset Tracking*
- UC-BSL-5 Equipment Monitoring and Line Visualisation*.

At **KLEEMANN Hellas** in Kilkis, Greece, two very-high-priority use cases and two high-priority use cases were implemented, the last one only simulated with software agents:

- UC-KLE-1 Maintenance Decision Support*
- UC-KLE-4 Scrap metal collection and bidding process
- UC-KLE-3 Scrap Metal and Recyclable Waste Transportation*
- UC-KLE-7 Ordering raw materials.

At **ELDIA SA** outside Thessaloniki, Greece, one very-high-priority use case was implemented:

- UC-ELDIA-1 Fill-level Notification – Contractual wood and recyclable materials management

Finally, a partial, concept-only implementation of one high-priority use case was done on behalf of **Atlantis Engineering** in Thessaloniki, Greece:

- UC-ATL-3 Searching for Recommended Solutions

1.4 Pilot-Specific Results

The three use cases implemented at **Boston Scientific** address seven of the fifteen relevant KPIs, in most cases meeting or exceeding the target. Both qualitative and quantitative results are reported, but for some of the KPIs relating to the concept-only UC-BSL-5, the system has not run long enough to produce significant results.

The use cases implemented at **KLEEMANN** address six of the fifteen KPIs, with results varying from close to target to significantly below or above the target. One factor contributing to this situation is the absence of a statistically significant amount of live data, another that the bidding part of UC-KLE-4 has only been simulated, not yet tested in real-world interactions.

The **ELDIA** use case addresses four of the fifteen KPIs. For two of them, actual numbers are available, with results exceeding the targets in both cases.

1.5 Other Results

The target KPI of 5 for the number of new, sustainable business models has been achieved. Furthermore, it was established in *D9.7 Cost, Benefit, and Risk Evaluation* that the COMPOSITION solutions are economically profitable for all pilot partners, both individually and as a whole.

1.6 Conclusions

The results show the successful implementation and benefits of the COMPOSITION platform, with the technology being used on all the pilot sites functioning well.

All the presented use cases met the requirements in terms of implementation and deployment. Measuring the outcome of the implemented use cases against the KPIs from the Description of Action, almost all of the use cases met or exceeded the targets.

In Boston Scientific, *UC-BSL-2 Predictive Maintenance* gave promising results, meeting or exceeding the targets on the relevant KPIs. *UC-BSL-3 Asset Tracking* showed great improvements in terms of cost savings and reduction in lost time looking for equipment. With *UC-BSL-5 Equipment Monitoring and Line Visualisation*, the system has not been running long enough to give any significant results for some of the KPIs, although with the full line visualisation, there will be an overall reduction in down-time.

At KLEEMANN, *UC-KLE-1 Maintenance Decision Support* met most of its targets, with cost savings for process monitoring and a reduction in down-time. For *UC-KLE-3 Scrap Metal and Recyclable Waste Transportation*, the forklift’s fuel consumption and cost were reduced by 4%, with further improvement expected if the system is expanded in the future. For *UC-KLE-4 Scrap Metal Collection and Bidding Process*, the pilot the bidding process was performed by simulation and showed expected results, but real-world interactions would be needed for a more quantitative evaluation.

For *UC-ELDIA-1 Fill-Level Notification – Contractual Wood and Recycle Materials Management*, the results were also positive with KPIs exceeding the targets in both cost savings and in time to replace a full container with an empty one.

2 Abbreviations and Acronyms

Table 1: List of abbreviations and acronyms

Abbreviation or Acronym	Meaning
API	Application Programming Interface
CLI	Command Line Interface
CMMS	Computerised Maintenance Management System
DFM	Digital Factory Model
DLT	Deep Learning Tool
DoA	Description of Acton
DSS	Decision Support System
ERP	Enterprise Resource Planning
HMI	Human Machine Interface
IIMS	Integrated Information Management System
MMS	Marketing Management Services

3 Introduction

The objective of *Task 8.4 Evaluation According to Specification* is to measure the outcome of the project against the user requirements with specific focus on stakeholder feedback captured in the analysis of the use cases.

3.1 Purpose, Context and Scope of this Deliverable

The deliverable aligns with COMPOSITION *Technical Objective 3.1: Implement, demonstrate and validate the COMPOSITION operating system in two multi-sided pilots*.

The evaluation methodology used was described in *D8.7 Evaluation Framework*, and selected results from *D8.4 Supply Chain Pilot II* and *D8.6 Value Chain Pilot II* are included, as are Lessons Learned collected in the final project development cycle in *WP2 Use Case Driven Requirements Engineering and Architecture*. The final status of the user requirements defined in WP2 is also reported.

The use cases implemented at the pilot sites have been run to evaluate outcome and performance in comparison with applicable Key Performance Indicators (KPIs) as defined in the Description of Action (DoA).

3.2 Content and Structure of this Deliverable

An overview of Lessons Learned in the final development cycle, the outcome of user validation and final status of User Requirements can be found in Section 4.

Section 5 describes the evolution of the final Use Cases, and Section 6 provides brief summaries of the Pilot Sites, listing their implemented Use Cases.

Section 7 describes the methods and tools used for the evaluation, the actual results are reported in Section 8, with Conclusions in Section 9.

Learned and changes to User Requirements reported in the final project development cycle.

cycle

4 Requirements Engineering

In the final development cycle, each work package has analysed and reported their RTD experiences, Lessons Learned in the development and integration work and other relevant knowledge gained in the process.

4.1 Lessons Learned – Final Cycle

Twenty-two Lessons have been learned in the final cycle of the project. They are listed in Table 2. Because of the high-level nature of most of the COMPOSITION requirements, this has mostly affected their implementation rather than their substance. And some Lessons, in particular originating from WP9, have been included for completeness, though they are more general in nature and not directly related to the WP2 requirements.

Table 2: Lessons Learned in the final cycle

Org	Experience and knowledge gained	Lesson Learned	Analysis	Requirement(s) affected
	WP1 Project Management			
FIT	During the pilot visits, the reviewers were hosted by the pilot partners, supported by the local technology partners. The visits were successful	Since the main goal of these visits was to see the influence of the technologies on the pilot processes, this setting turned out to be suitable	The setting is recommendable for reviewer visits in other projects	N/A
ATL	Local technical providers worked as local facilitators and provided all important details and information to the reviewers. The complete technical work of the project was available to the reviewers	Since the main goal was to see the technologies work in real time on pilot shop floors, the process of knowing the whole technical aspects of the project turned out to be suitable for all: reviewers, end users and technical partners	The setting is recommendable for reviewer visits in other projects	N/A
	WP2 Use Case Driven Requirements Engineering and Architecture			
IN-JET	It is difficult to foresee and plan for the specific obstacles that will be encountered in complex industrial environments	At the technical review at BSL, Kai Peters reported that it would be useful if, in particular, the non-technological requirements and constraints of real-world industrial production sites could be identified at an earlier stage	Industrial requirements are very specific and not always obvious. After identifying the barriers, the BSL use cases have been successfully implemented	None
ATL	Use cases provide information concerning only specific parts of the manufacturing process on the shop floor. It is difficult to	The scenarios should be designed based on the most critical parts of the production line, and they should be revised regularly during the project. Changes based	Initial requirements describe part of the manufacturing process. More requirements related to branches and alternative scenarios could be defined in future	Several (directly and indirectly)

Org	Experience and knowledge gained	Lesson Learned	Analysis	Requirement(s) affected
	predict and prevent breakdowns on more complex situations depending on more than the described scenarios	on different workflows in the scenarios, or branched scenarios should also be considered. It was suitable for COMPOSITION, because we were able to update the scenarios and the use cases requirements throughout the project	steps	
	WP3 Manufacturing Modelling and Simulation			
CERTH	DFM should offer a resource catalog to other tools	A common way to retrieve all data for a specific resource is missing	Software components such as UIs or analytics tools want to retrieve all the data connecting to a resource. The DFM API was extended to provide a complete resource catalog to the project components. For example, UIs can query a DFM instance and receive all the data sources that are connected to a machine (analytic tools predictions, static information about location, installed sensors, descriptions, etc., and data streams of MQTT topics in order to retrieve real-time sensor data from BMS)	COM-152, COM-153
ATL	DSS should offer the possibility to the user to receive the notifications on a mobile device	Mobile devices are used by workers on manufacturing shop floors to communicate between them. Users would like to also have the notifications about maintenance or breakdowns on their mobile during their work day	Development of a mobile application that allows the users to receive notifications while working on the shop floor. The mobile application is easy to configure, uses the Wi-Fi of the shop floor or the 4G mobile network. The application is based on an MQTT broker which sends the notifications to the mobile device and the mobile device has an MQTT client to receive the messages	COM-101, COM-100
ATL	DSS should offer the possibility to the users to rate the notifications and	When the users received notifications, they wanted to be able to comment on them, rate their relevance, and evaluate	The developed mobile application was extended and the functionality of commenting on the received notifications as	COM-95, COM-93

Org	Experience and knowledge gained	Lesson Learned	Analysis	Requirement(s) affected
	comment on them.	how helpful they were for their work.	well as rating them was added to it. The functionality uses the application's MQTT client to send the rating messages back to the DSS.	
ATL	DSS should be able to store feedback from the mobile application and be able to use it for extracted knowledge	Users send their feedback through the mobile application. Shop floor managers need to know how the implemented system works and if there are ways to improve it	A KPI mechanism of counting the notifications rating and measuring the number of notifications was added to the DSS. The database schema was redesigned to accommodate the changes and all notifications feedback was stored in the DSS database. The KPI mechanism retrieves the data from the database to create graphs and charts about the mobile feedback	COM-101, COM-100, COM-95; COM-93
	WP4 Secure Data Management and Exchange in Manufacturing			
ATOS	Need to create an authentication and authorization mechanism for both users and applications	The ATOS authentication and authorization tool created accounts for both users and applications	There are many different users in the project and they are responsible for different use cases. There are also components which participate in many use cases. ATOS recognised the need for different accounts for applications and users and created the policies and the accounts for all users and applications participating in the COMPOSITION project	Several (mainly those concerning the A&A mechanism)
ATOS/ Others	Other technology providers needed to incorporate ATOS security component in their applications	The need to protect data and confidential elements on the shop floor led to the existence of an A&A mechanism in the project created by ATOS	Technology provider incorporated the ATOS A&A component using the implemented policies. They were authorised in the component as end users or technical providers and their applications used the accounts created specifically for them. It proved valuable for testing and development and should be considered in other projects, too, especially where there are	Several (mainly those concerning the A&A mechanism)

Org	Experience and knowledge gained	Lesson Learned	Analysis	Requirement(s) affected
			several overlapping components	
	WP5 Key Enabling Technologies for Intra- and Interfactory Interoperability and Data Analysis			
NXW	During the integration and testing phase, COMPOSITION components that consume data from the BMS sometimes need this data to be sent "on-demand"	An API to control the replay mechanism (start, stop) could be useful	When integrating the whole COMPOSITION platform, having a way to test loops among components is vital. That's why providing an API to trigger the start/stop of the data replay could simplify part of the testing/debugging phase	Several (directly and indirectly)
ATL	DSS needs to receive data in a continuous way, either as packets of data or as binary data each time	A DSS sub-component to regulate the data streaming process is useful	A data streaming process is needed for all components receiving data from the sensor network and the other COMPOSITION components. The DSS data streaming sub-component proved to be very efficient. It should be considered a separate sub-component for other projects, too.	None
	WP6 COMPOSITION Collaborative Ecosystem			
NXW	The Marketplace Management Services component is directly handling agent containers	MMS must be allowed to use the Portainer API for manipulating containers	Portainer must be configured to allow MMS to access its APIs for container management	Several (directly and indirectly)
NXW	Marketplace Management Services API has to be tested after deploying its container, even if its endpoints are not public	MMS API can be tested using Portainer CLI	Portainer CLI has direct access to the container and it can be used to test all its functionalities	Several (directly and indirectly)
NXW	Marketplace Management Services API must have access to APIs for container management but only for some specific components (the agents)	In Portainer we can create different environments connected to each other	The Marketplace Management Services API can be connected to a specific environment with a network connection and can use API only in this environment	Several (directly and indirectly)
CERTH	Collaborative Manufacturing	To support use cases such as UC-ATL-1, the	In use cases such as UC-ATL-1, the Marketplace	COM-59, COM-62,

Org	Experience and knowledge gained	Lesson Learned	Analysis	Requirement(s) affected
	Services Ontology should cover software solution concepts	Marketplace should be able to support the description of software solution concepts	should enable the matchmaking between companies based on software solution terms. Therefore, the Collaborative Manufacturing Services Ontology should be extended	COM-85
CERTH	The Ontology Querying Component and its exposed API must be part of the Matchmaker software package	The complete Matchmaker framework should have a common way of offering storing, querying and reasoning capabilities to the COMPOSITION Marketplace	The need to share the same resources fast and effectively, both for querying and inference, indicates the design of a complete semantic framework. The COMPOSITION Matchmaker is this framework and contains the Ontology API as well. (This is not a stand-alone component as it was in the initial version)	COM-148
	WP7 Integration of Internal and External Elements			
ATL	The ecosystem needs to be seen as a complete application that incorporates all components in one toolkit, seamless to the final user. This may be achieved by integration of all internal and external components of the COMPOSITION ecosystem	Definition of basic guidelines for the design of HMI, as well as definition of the most suitable framework to work with will be useful	Discussion between all technical partners to find the most suitable way to create a seamless environment could preferably take place at an earlier stage of the project, including definition of basic guidelines for the UIs to follow throughout the HMI design of the components	Several (mainly those relating to HMI design)
CNET	To integrate all COMPOSITION components, a common HMI is also required	In order to create a unified view of the COMPOSITION sub-components, a common menu and a common menu sub-component should be implemented	Creating a common menu and defining the framework and suitable application early on in the development work will save time and effort later. The use of web-components containing the common HMI menu facilitates overcoming the obstacles of implementing a single framework due to different architectures and programming languages for different components	Several (mainly those relating to HMI design)

Org	Experience and knowledge gained	Lesson Learned	Analysis	Requirement(s) affected
	WP9 Business Models, Dissemination and Exploitation			
ATL	We need to book events in advance and organise them in detail	During the COMPOSITION participation of several events, people interested in the project contacted us. Targeted persons were contacted by COMPOSITION employees during the events, because they were experienced in a specific area which helped the project	Targeted communication with key stakeholders helped the growth of the COMPOSITION network. The practice proved successful and other projects can follow the example	N/A
ATL	Dissemination to more conferences, expos, etc., is both useful and rewarding	Participation in academic conferences, expos, pitch events, etc., improved during the later phases of the project	The last period of the project was the most successful in terms of dissemination to conferences, expos and events. This was possible due to the technological advancements and the first implementation iteration	N/A
ATL	Organising the developed components into products and solutions aimed at specific market segments makes it more straightforward to realise exploitation potential and easier to understand from the user's point of view	Cataloguing of products and outcomes in market segments is advantageous, both for facilitating exploitation planning and for better understanding from the user's point of view	For the end users to understand the value of the components and products developed in COMPOSITION, it was necessary to organise them in market segments that were relevant to them. At the same time exploitation possibilities became clearer	N/A

4.2 End User Validation of Requirements

126 requirements have been implemented, half of which have been validated by the end users, who tested COMPOSITION components and evaluated the improvement of shop floor operations in one or more iterations. The evaluation was done by end users at the pilot sites, and this worked particularly well, because users dedicated time for the process during their working day. The end-user feedback led to changes to the components, as is also apparent from the Lessons Learned above. Where applicable, the user requirements associated with the components were validated based on their ease of use, relevance for the specific manufacturing operation and logic of the User Interfaces.

The requirements with final Status implemented are typically quite technical in nature and not transparent to the end users. The technical requirements have been tested and verified by the technical partners, but end user validation is not applicable.

The final requirement distribution according to Status is shown in Figure 1.

4.3 Requirement Status

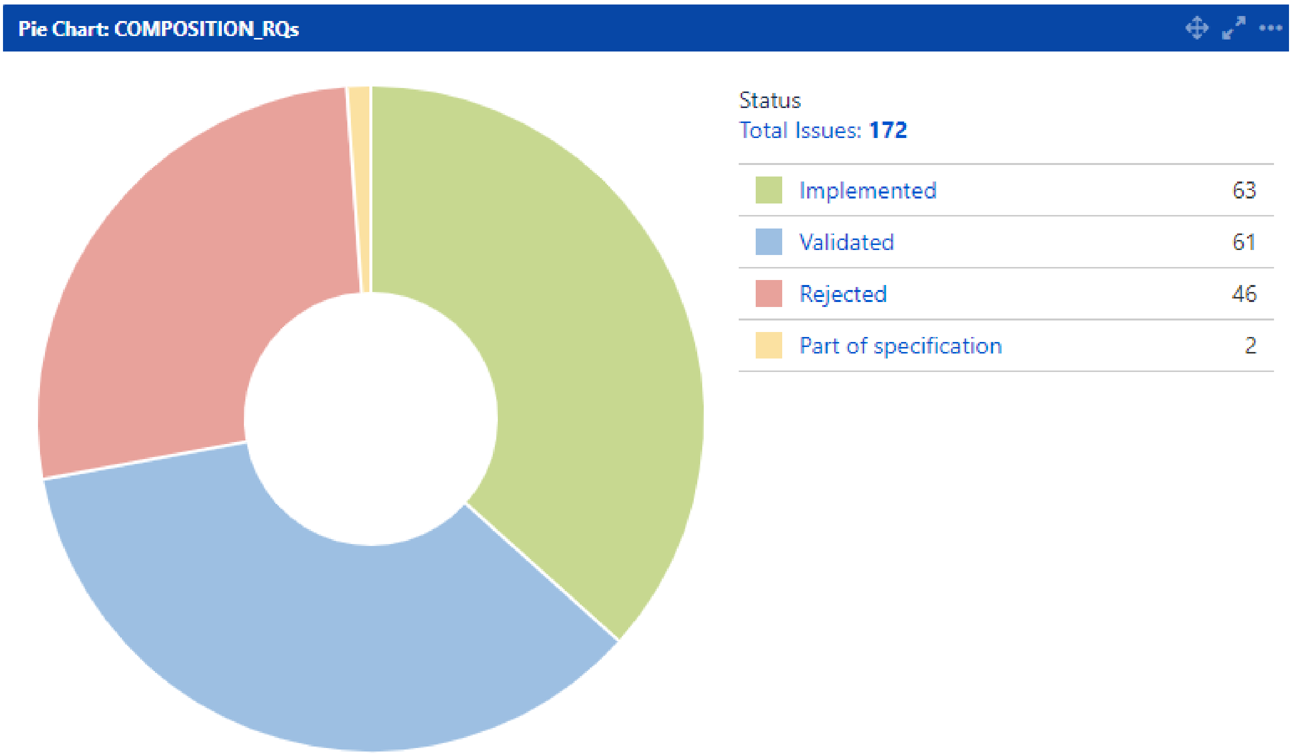

Figure 1: Status of User Requirements

At the time of writing, 61 requirements have been implemented and validated, 62 have been implemented, 1 Blocker has been resolved, while 2 requirements are under implementation (status Part of Specification). 46 requirements have been rejected, 5 of which have been withdrawn, 12 are Duplicates and 29 have been rejected as Out of Scope. Some requirements rejected as Out of Scope in the final cycle are not Out of Scope for the COMPOSITION solutions, but Out of Scope for the project due to lack of time.

5 Evolution of COMPOSITION Use Cases

Throughout the duration of the project, the specification of the COMPOSITION use cases underwent a continuous (re-)assessment and refinement. The approach was inspired by the underlying principle of the 'Double Diamond' design process model (British Design Council, 2007), where the project team members initially keep their perspectives wide to explore as many ideas as possible, and later on refine and filter out what they want to pursue. This practice helps to keep focus on those use cases that are most relevant and promise most added value from a technology, impact and exploitability point of view, as recommended by the reviewers at the M18 Review.

5.1 First Iteration of Use Cases

The first iteration, shown in Table 3, resulted in a list of use cases that all partners agreed would be potentially useful, feasible to implement, innovative, exploitable and within the scope of the COMPOSITION objectives. The initial use cases are described in detail in *D2.1 Industrial Use Cases for an Integrated Information Management System.*

Table 3: First iteration of COMPOSITION use cases

Use Case ID	Name
UC-BSL-1	NC Monitoring
UC-BSL-2	Predictive Maintenance
UC-BSL-3	Component Tracking
UC-BSL-4	Automatic Solder Paste Touch Up
UC-KLE-1	Maintenance Decision Support
UC-KLE-2	Delayed Process Step
UC-KLE-3	Scrap Metal and Recyclable Waste Transportation (from Bins to Container)
UC-KLE-4	Scrap metal collection process
UC-KLE-5	Scrap metal bidding process
UC-KLE-6	Determining price for scrap metal with ELDIA acting as Logistician
UC-KLE-7	Ordering raw materials
UC-ELDIA-1	Fill-level notification – Contractual Recyclable materials (paper, plastics) recyclable waste management
UC-ELDIA-2	Fill-level notification – Contractual wood waste management
UC-ATL-1	Selling software/Consultancy
UC-ATL-2	Searching for solutions
UC-ATL-3	Searching for recommended solutions
UC-ATL/NXW-1	Integrate External Product into Own Solution
UC-NXW-1	Decision Support over Marketplace

5.2 Prioritisation of Use Cases

As a first filtering step, the consortium applied a prioritisation according to the following factors:

- Importance for end users
- Importance for technology partners
- Impact on project objectives
- Innovation potential
- Exploitation potential

This resulted in a classification into three tiers as depicted in Table 4. During this process, an additional use case was defined (UC-BSL-5).

Table 4: First version of prioritised use cases

Tier	Use Case
Tier 1 Very High Overall Priority	UC-BSL-2 Predictive Maintenance
	UC-KLE-1 Maintenance Decision Support
	UC-KLE-4 Scrap metal collection process
	UC-KLE-5 Scrap metal bidding process
	UC-KLE-6 Determining price for scrap metal with ELDIA acting as Logistician
Tier 2 High Overall Priority	UC-BSL-5 Equipment Monitoring
	UC-ELDIA-1 Fill-level Notification – Contractual solid recyclable waste management
	UC-ELDIA-2 Fill-level Notification – Contractual wood waste management
	UC-KLE-2 Delayed Process Step
	UC-BSL-3 Component Tracking
	UC-ATL-3 Searching for recommended solutions
Tier 3 Medium Overall Priority	UC-BSL-1 NC Monitoring
	UC-KLE-3 Scrap Metal and Recyclable Waste Transportation
	UC-BSL-4 Automatic Solder Paste Touch Up
	UC-KLE-7 Ordering raw materials
	UC-ATL-1 Selling software/consultancy
	UC-ATL-2 Searching for solutions
	UC-ATL/NXW-1 Integrate external product into own solution
	UC-NXW-1 Decision support over marketplace

5.3 Intermediate List of Prioritised Use Cases

The ranking in Table 4 was then taken as baseline and continuously refined. Critical reviews of all use cases led to the addition of new use cases, deletion of existing use cases because they were assessed as not relevant enough, and combination of existing use cases because of their similarity. As of M15, two more use cases were added (UC-BSL-6 and UC-BSL-7), one use case was dropped (UC-BSL-1) and two use cases were combined (UC-ELDIA-1 and UC-ELDIA-2 into UC-ELDIA-1). This stage was reported in *D2.5 Lessons Learned and Updated Requirements Report I* and visualised in Table 5.

Table 5: Intermediate version of prioritised use cases (M15)

Tier	Use Case
Tier 1 Very High Overall Priority	UC-BSL-2 Predictive Maintenance
	UC-KLE-1 Maintenance Decision Support
	UC-KLE-4 Scrap metal collection and bidding process
	UC-ELDIA-1 Fill-level Notification – Contractual wood and recyclable materials management
Tier 2 High Overall Priority	UC-BSL-5 Equipment Monitoring and Line Visualisation
	UC-KLE-2 Delayed Process Step
	UC-BSL-3 Component Tracking
	UC-ATL-3 Searching for recommended solutions

Tier	Use Case
Tier 3 Medium Overall Priority	UC-KLE-3 Scrap Metal and Recyclable Waste Transportation
	UC-BSL-6 Visualisation of "hot items" for material management
	UC-BSL-7 Automatic long-term tracking of high value materials for physical security
	UC-BSL-4 Automatic Solder Paste Touch Up
	UC-KLE-7 Ordering raw materials
	UC-ATL-1 Selling software/consultancy
	UC-ATL-2 Searching for solutions
	UC-ATL/NXW-1 Integrate external product into own solution
	UC-NXW-1 Decision support over marketplace

5.4 Final Version of Prioritised Use Cases

The final version of the use cases is presented in Table 6. One more use case was dropped (UC-BSL-6), two were combined (UC-BSL-3 and UC-BSL-7 into UC-BSL-3 Asset Tracking) and two were re-prioritised (UC-KLE-2 and UC-KLE-3).

Table 6: Final version of prioritised use cases

Tier	Use Case	Implemented
Tier 1 Very High Overall Priority	UC-BSL-2 Predictive Maintenance	Yes
	UC-KLE-1 Maintenance Decision Support	Yes
	UC-KLE-4 Scrap metal collection and bidding process	Yes
	UC-ELDIA-1 Fill-level Notification – Contractual wood and recyclable materials management	Yes
Tier 2 High Overall Priority	UC-BSL-5 Equipment Monitoring and Line Visualisation	Concept only
	UC-KLE-3 Scrap Metal and Recyclable Waste Transportation	Yes
	UC-BSL-3 Asset Tracking	Yes
	UC-KLE-7 Ordering raw materials	Only simulated with software agents
	UC-ATL-3 Searching for recommended solutions	Concept only, partial implementation
Tier 3 Medium Overall Priority	UC-KLE-2 Delayed Process Step	No
	UC-BSL-4 Automatic Solder Paste Touch Up	No
	UC-ATL-1 Selling software/consultancy	No
	UC-ATL-2 Searching for solutions	No
	UC-ATL/NXW-1 Integrate external product into own solution	No
	UC-NXW-1 Decision support over marketplace	No
Business Model Use Cases	UC-BM-1 Waste notification, certificates and collection	Yes
	UC-BM-6 Contract fulfilment and supply chain management	Only simulated with software agents

This final list is the basis for the use cases that have in fact been implemented within the project, including two additional business model use cases: UC-BM-1 which is a Subcase of UC-KLE-4 and UC-BM-6 which is a Subcase of UC-KLE-7. The business model Subcases are implemented as part of the use cases they are derived from.

6 Brief Description of Pilot Sites and Use Cases

6.1 Boston Scientific, Ltd., Ireland

Boston Scientific Limited (BSL) is one of the largest medical device companies in the world with over 23,000 employees worldwide. Founded in 1979, its products are sold in over 100 countries.

Boston Scientific Limited (Clonmel) is the largest in terms of Value of Production in the Boston Scientific network of plants. It is the sole manufacturer of Pulse Generators (Pacemakers and Implantable Cardiac Defibrillators) in the network. It employs about 900 employees. The Clonmel plant has a long history of producing complex active electronic medical device implants and was set up originally in 1998 to start pacemaker manufacturing. The plant is engaged in all elements of manufacturing (quality, product performance, engineering operations, HR and finance) and has been responsible for all process development activities related to Pulse Generators since 2006. The process development organisation has been involved in numerous new product introductions[1] and is the lead organisation on site to introduce new products and technology. In addition to its core process development activities, the group has a dedicated software and test (electronic) engineering team. The Process Development Group's current interests are in simulation, analytics, test algorithms, laser-based and additive manufacturing technologies.

6.1.1 Implemented Use Cases

Very high priority:

UC-BSL-2 Predictive Maintenance

High priority:

UC-BSL-3 Asset Tracking

(UC-BSL-5 Equipment Monitoring and Line Visualisation – Concept-only)

6.2 KLEEMANN Hellas, Greece

KLEEMANN (KLE) was founded in 1983, originally based on the know-how and licensing of KLEEMANN HUBTECHNIK GmbH. It operates both in the manufacturing and the trading of complete lift systems. The head offices are based in Kilkis, Northern Greece, with offices and subsidiaries in 10 territories serving more than 90 countries worldwide. They apply a lean manufacturing concept for their batch production processes for lift assemblies, lift systems, parking systems, stair lifts and moving walks. The range of products comprises domestic and commercial lift systems, including car parking and multi-storey building lift systems. Recently it has invested in the new series of 'Green Edition Lifts', having introduced improved quality of motion by means of the C-LRV electronic valves, and energy savings of up to 50% thanks to the inverter drive and special automation circuits. KLEEMANN ranks among the large international companies in the lift industry, with manufacturing facilities in Greece, China and Serbia. The company provides more than 10,500 new systems annually (2% of the world's new lift units). In Greece, the company holds a leading position (with a 72% market share of total units installed).

6.2.1 Implemented Use Cases

Very high priority:

UC-KLE-1 Maintenance Decision Support

UC-KLE-4 Scrap metal collection and bidding process

High priority:

UC-KLE-3 Scrap Metal and Recyclable Waste Transportation

(UC-KLE-7 Ordering raw materials – Simulated with software agents only)

[1] Such as spinal cord stimulators and deep brain stimulators

6.3 ELDIA SA, Greece

ELDIA is the largest waste management company in Northern Greece and one of the leading dealers of recycled materials in Europe. Founded in 1997, ELDIA offers services providing solutions to solid waste management and disposal issues of industrial and commercial enterprises, local government or organisations of the broader public sector. ELDIA undertakes the screening of all commercial and industrial waste in order to recover materials (paper, wood, plastics, metal, pallets and glass) and promote the recycling industries. It handles civil and industrial waste with quality standards (ISO 9001:2008, ISO 14001:2004 and ISO 18001:2007) with focus on environmental protection in every sector, providing the best cost to efficiency ratio in waste collection and recycling.

In collaboration with Herrco SA, a subsidiary firm of ELDIA, a Recovery and Recycling plant is in operation, recovering both commercial-industrial and municipal waste, such as wood, packaging paper, mixed paper, TetraPak, aluminium cans, ferrous cans, glass bottles and many different types of plastics. All of the aforementioned materials are being baled and then forwarded to various recycling plants domestically and abroad.

6.3.1 Implemented Use Cases

Very high priority:

UC-ELDIA-1 Fill-level Notification – Contractual wood and recyclable materials management

6.4 Other Use Cases

Initially, partners ATL and NXW defined use cases aimed at providing software via the COMPOSITION ecosystem, but as described in Section 5, the prioritisation process left only one of these, the high-priority use case *UC-ATL-3 Searching for recommended solutions*. Brief descriptions of the two partners are given below.

6.4.1 Atlantis Engineering, Greece

ATLANTIS Engineering is an SME whose main activities include the support of daily production activities in different factories with simple and advanced manufacturing systems, the organisation and computerisation of maintenance departments, the customised maintenance consulting and training, and asset life cycle optimisation.

ATLANTIS has long standing experience in the industrial manufacturing domain. The expertise of the company is mainly in the decision support for the management and optimisation of production activities and assets' life-cycle, in the design, interconnection and implementation of models and protocols for the manufacturing sector, and in the streamlining of the various maintenance related processes (predictive, condition-based, and reactive).

Parts of the Supply Chain/Interfactory Pilot will be deployed by ATLANTIS for software upgrade and deployment.

6.4.1.1 Implemented Use Cases

High priority:

(UC-ATL-3 Searching for recommended solutions – Partial implementation, concept-only)

6.4.2 Nextworks, Italy

Nextworks, located in Pisa, Italy, is a dynamic SME that operates in the IT and Telecommunications sectors. Nextworks has long-term experience and proven skills in the frameworks of IoT, wireless, access and transport networks, digital video encoding and transport, control and automation, design and development of complex software systems on both traditional and embedded platforms.

The role of Nextworks is two-fold: as a pilot in the Supply Chain/intrafactory domain, and as technology and service provider in both the value chain and the supply chain use cases, specifically for factory premises and production line monitoring and management. These services will be provided based on information collected both from the field (production line and BMS), and where possible from other stakeholders' ERP systems.

Decisional processes inside the production line will also be supported, enhancing their functionality using professional analysis tools offered by the COMPOSITION marketplace.

No use cases have been implemented specifically for Nextworks, but UC-ATL-3 is also applicable to their business areas.

7 Evaluation Plan and Data Collection

7.1 Plan

The evaluation plan, adapted from "Six Steps to Effective Evaluation" by Glenaffric (Glenaffric, 2007), was described in *D8.7 Evaluation Framework*, which also covers the first three steps of the process, see Figure 2.

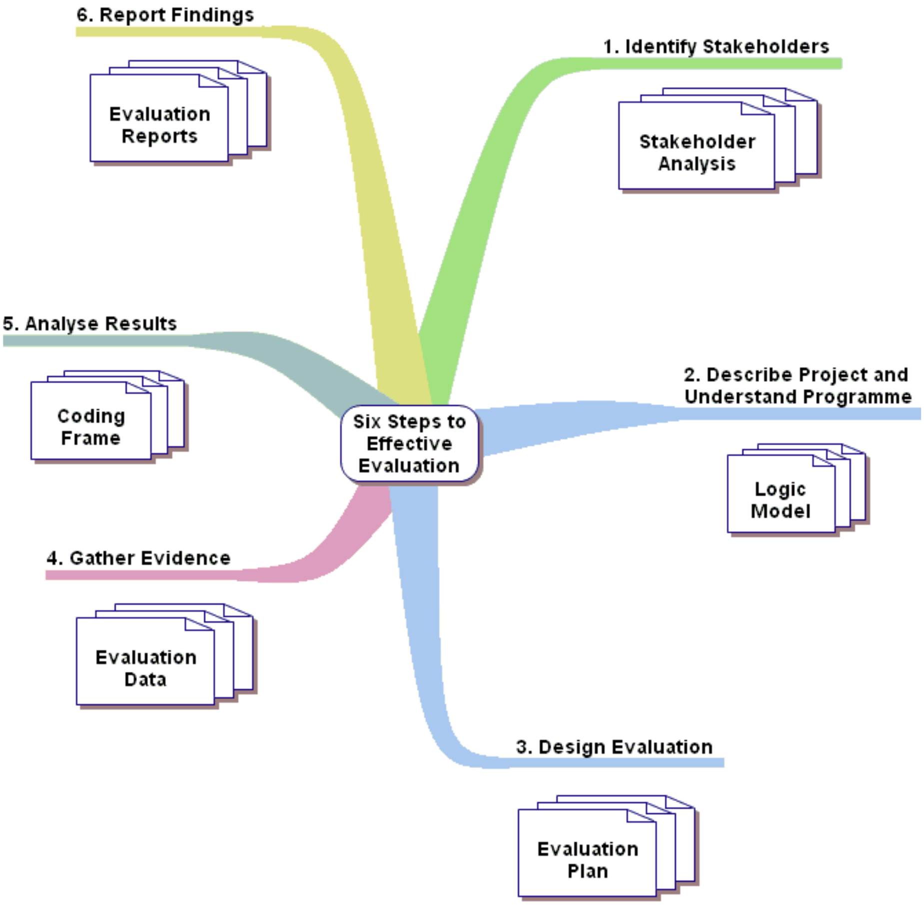

Figure 2: The Six Step approach to effective evaluation (Glenaffric, 2007)

This report, in turn, covers the last three steps: Gather evidence, analyse results and report findings.

7.2 Data Collection Methods and Tools

There are two main approaches to collecting data. The first is quantitative in nature, mainly numeric, and focused on measurable goals. Obtaining quantitative results generally requires extraction and analysis of data pre- and post-implementation of the solution under test.

The second is qualitative, which helps provide more depth in understanding an issue. Methods include observations and individual or group interviews.

Both approaches were applicable to COMPOSITION, depending on the environment, the pilot, the use case and the KPI in question.

The use cases implemented at the pilot sites have been run to evaluate outcome and performance against the relevant Key Performance Indicators listed in Table 7.

COMPOSITION use cases leverage on the integration, correlation and aggregation of data from several heterogeneous data sources, and the data is collected in real time by sensors, acquired from existing stores or also made available by direct observations and worker interviews.

Each application chooses the best approach to build its own datasets depending on the needed processing models and algorithms. None-the-less, a well-defined approach for data collection is of paramount importance to ensure:

- A comparable level of details and granularity for the data
- A common interpretation of the data
- Communications conformity among interconnected components.

7.3 Baseline Data

Availability and accessibility of baseline data are prerequisites for assessing performance improvements attributable to the implemented solutions. For the intrafactory use cases implemented at BSL and KLEEMANN, baseline data are available from the existing Manufacturing Execution Systems or Enterprise Resource Planning Systems, etc. Historical data exist covering an extended period, in the KLEEMANN case dating back 10 years, for BSL up to 9 years, depending on the equipment.

Datasets and baseline data for each use case are shown in Section 8.

8 Evaluation of Pilots and Use Cases

8.1 Key Performance Indicators

The individual use cases are evaluated against applicable KPIs as these are defined in the Description of Action, see Table 7. The numbers in column 2 are added for easy reference elsewhere in this document.

Table 7: KPIs from DoA

Area	Key Performance Indicator	Target
Improvement from collaborative, real-time efforts towards down-time and logistics inefficiencies (affects **availability**)	1. Overall reduction in down-time from failures & bottlenecks	15%
	2. Cost savings for process monitoring	25%
	3. Reduction of amount of non-critical spare parts availability	10%
Improvement from enhanced integration of manufacturing and logistics processes (affects **performance**)	4. Reduction in cycle-times from process monitoring & behaviour	10%
	5. Better interaction with the suppliers, recycling companies	10%
	6. Cost improvements from improved process monitoring	25%
Improvement in manufacturing quality from modelling, simulation and communication (affects **quality**)	7. Improvement in manufacturing quality	5%
	8. Reduction of order-to-delivery time and shipping costs	10%
	9. Reduction in scrap and repair costs	50%
Innovative services, models and practices optimising manufacturing and logistics processes (Improved **business** and innovative service models)	10. Number of new, sustainable business models developed in the project	5
	11. User acceptance ratio of validated ICT security and trust measures	>95%
Reductions expected in the efforts for integration or reconfiguration of today's automation systems	12. Total reduction in the efforts for integration or reconfiguration	30%
	13. Improvement of non-effective procedures with decentralisation	20%
	14. Reduction in time for optimisation of products/services	10%
Improved reaction to market changes using holistic global and local optimisation algorithms	15. Improvement in time-to-market ability	15%

8.2 Results from the BSL Pilot

All Use Cases in the BSL Pilot are intrafactory use cases, which are described in detail in *D8.6 Value Chain Pilot II*. Selected results are collected below.

8.2.1 Use Case UC-BSL-2 Predictive Maintenance:

Pre-COMPOSITION:

When a fan in one of the reflow ovens in the production line failed, reactive maintenance was the only method used: replace it once it breaks. In case of a fan failure, there would be a failure analysis, then the appropriate technician would be assigned to repair. This can take up to 5 hours depending on the location of the fan, with fans located at the top taking longer due to the heat.

The company would also carry out preventive maintenance, but this also carries a number of issues: it creates unnecessary work, it is labour intensive, and preventive maintenance often does not uncover critical issues that arise between maintenance intervals.

With COMPOSITION, Predictive Maintenance techniques were introduced as a way to solve these issues.

For the trial, the solution was implemented in the line used for research and development of new manufacturing processes – i.e., not integrated into a running production line – which was considered in the analysis.

Post-COMPOSITION:

Deploying this use case, fan replacement can be planned ahead and solved with a targeted approach. With analysis of the new generated data, failure of the fan can be predicted, and down-time optimised and reduced.

In addition to the reduction in down-time we also took into consideration the number of unscheduled maintenances since the use case was implemented. The frequency of unscheduled maintenance has also decreased since the project began. While the exact reduced number of unscheduled maintenances is directly related to the oven in the R&D line, the results clearly indicate that a similar reduction in unscheduled maintenances in the running production line can be expected.

Data collected:

- Unscheduled Maintenance
- Down-time associated with oven failure
- Cost of maintenance.

During the project, acoustic data were collected in addition to data for Set Point, Process Value and Output Power.

Table 8: Baseline data for UC-BSL-2

Oven on line	Approx. no. of years of data	Recorded data			No. of blower failures 2010-2017
		Set Point	Process Value	Output Power	
Brady	7	Yes	Yes	Yes	2
Tachy	8	No	Yes	Yes	4
Rhythmia	4	No	Yes	Yes	6
NMD	9	No	Yes	Yes	5

Table 9: Unscheduled Maintenance (2010-2019) for the Reflow Oven where UC-BSL-2 was deployed

Type	Date Completed	Sched. Start Date	Description
Unscheduled	27/06/2018 10:04	27/06/2018	Replace starter capacitor for heat zone 3
Unscheduled	03/02/2016 09:42	03/02/2016	Replace blower motor
Unscheduled	16/07/2014 02:26	15/07/2014	Blower Motor Faulty
Unscheduled	30/04/2014 14:49	14/04/2014	Flux exhaust blowers not working - faulty controller
Unscheduled	10/10/2013 19:15	10/10/2013	Heat zone fault
Unscheduled	02/09/2013 05:33	02/09/2013	Heat zone over temp
Unscheduled	04/02/2013 09:19	15/01/2013	Cooling zone fault

Type	Date Completed	Sched. Start Date	Description
Unscheduled	16/10/2012 05:07	16/10/2012	Replaced motor fan capacitor
Unscheduled	13/03/2012 06:02	13/03/2012	Over Temp Issue
Unscheduled	04/10/2011 06:25	03/10/2011	Over temp issue
Unscheduled	31/03/2011 08:33	31/03/2011	Replace blower motor on Zone 7
Unscheduled	20/02/2011 08:46	20/02/2011	Blower motor seized
Unscheduled	03/06/2010 14:02	03/06/2010	Blower motor changed heat 15
Unscheduled	01/06/2010 14:46	01/06/2010	Blower motor failure heat 5

Table 10: Dataset for UC-BSL-2

Type	Description	Format	Interval
Acoustic data	Each sensor records 20 seconds of audio data and every 5 minutes to calculate the amplitude in dB	The amplitude is stored for each of the 5 sensors in a single timestamped CSV file.	Data from three different trials is available in the following intervals: • from 10 January to 16 January 2018 • from 16 January to 4 February 2018 • from 16 February to 9 March Data started being sent to the cloud since: May 2018
Oven sensor	Each blower logs two values: the measured temperature [°C] and the output power at the solid-state relay of the reflow. Records are sampled every 5 minutes.	Textual data structured as a list of records, one per row. Each row is timestamped.	Historic Data since; November 2013 Data started being sent to the cloud since: May 2018
Oven events logs	The list of events occurred in the oven (e.g., status, used recipe, warning, etc.)	Textual description of the events, one per row. Each row is timestamped.	Historic Data since: November 2013 Data started being sent to the cloud since: May 2018
Workers feedback	Operators can provide feedbacks based on experience, to correctly identify and solve a problem	Data aggregation rules and constraints (e.g., several consecutive warnings can be considered as an oven fault)	-

Table 11: Results from UC-BSL-2 Predictive Maintenance

KPI No[2]	Key Performance Indicator	Unit	Pre	Post	Change	Target
1	Overall reduction in down-time from failures & bottlenecks	Hrs Down-time associated with failure	Up to 5	Up to 3	40%	15%
2	Cost savings for process monitoring	Number of maintenances per year	3	2	33%	25%
9	Reduction in scrap and repair costs	Costs for scrappage due to equipment failure + Scrappage costs from other non-compliant materials Unscheduled maintenance	 3	 2	50% 33%	50%
12	Total reduction in the efforts for integration or reconfiguration	Qualitative, see below			25%	30%
14	Reduction in time for optimisation of products/services	Same as KPI 2			33%	10%

8.2.1.1 Interpretation of Results

KPI 1: Pre-COMPOSITION – Down-time can take up to 5 hours depending on the location of the fan.

Post-COMPOSITION – This time is reduced to a maximum of 3 hours.

Assuming all fan failures will be predicted, the location of the faulty fan will be known, and the replacement can be scheduled ahead of time. Therefore, the reduction in time to deal with a fan related issue will be 40%.

With the current prediction window, a repair might still have to occur during production active hours. However, with the future increase in the prediction window, this would be dealt exclusively outside production time, so this could be decreased and will be considered maintenance only and not actual productive down-time.

KPI 2: Post-COMPOSITION – With the fan failure prediction, the additionally generated data and analyses, the number of maintenances can now be optimised and reduced.

From what has been assessed so far, the preventive maintenance procedures can be reduced to the minimum.

(This is not a final number since before any process is altered, it has to go through a maintenance change approval process authorised by the process development team as well as the regulatory team. Due to the nature of the products that Boston Scientific manufactures, those decisions need more than one year of stable data).

KPI 9: Post-COMPOSITION – No fan failures occurred during the time that data was being collected. However, the system has been giving correct prediction and is working properly. Scrappage of non-compliant material will always occur, however, since 50% is usually attributed to manufacturing equipment failures, we can confirm that the prediction of 50% of reduction costs due to scrapped material is valid. For repair costs, the case is the same as for KPI 2, i.e., a reduction of 33%.

[2] From Table 7

As well as scrap, there is also a reduction in repair costs as less maintenance will occur, looking at the amounts of unscheduled maintenances per year.

KPI 12: Qualitative: When we mentioned 30% to the personnel in charge of the evaluation of the COMPOSITION platform, they mentioned there are usually 4 main common causes of oven failure: fan, traveller belt, heaters and exhaust. Eliminating one of the possible causes when a failure occurs, will naturally lead to a 25% reduction in time analysing if the oven failure was due to a faulty fan.

Pre-COMPOSITION – Alarm would be triggered by any overall failure in the equipment (fan or otherwise) and a technician would have to analyse where the failure happened and assign it to the correct maintenance technician

Post-COMPOSITION – Specific fan failures are now predicted (and specific alarms are displayed on the COMPOSITION interface), so the time to detect if the failure was due to a faulty fan is minimised.

KPI 14: Post-COMPOSITION – It is easier for the technician to perform repairs. As mentioned for KPI 2, the preventive maintenance frequency can now be reduced to the minimum, which leads to a 33% improvement in optimisation.

8.2.2 Use Case UC-BSL-3 Asset Tracking

Pre-COMPOSITION:

Before COMPOSITION, there was no standardised process targeting this problem, employees had to search laboriously and manually for lost components/equipment, which were required for validation or calibration, with some not being found for long periods or at all. On average, 25% of the equipment due for calibration misses the deadline, because it was missing at the time due to misplacement.

Post-COMPOSITION:

With COMPOSITION implemented, the employee only has to log into the COMPOSITION dashboard, and the equipment is displayed on a live visualisation screen. With this solution, the time taken to find the equipment has gone from an average of 45 minutes to 10 minutes.

The KPIs for this use case are based on the equipment that is tagged within the lab space, since this was a pilot implementation. Tagging all the equipment would be an additional investment that was not budgeted for this project, but it is a possibility for the future which is being discussed internally at BSL.

The costs for the evaluation system was a one-off payment used for testing, but there would be additional costs for use as a commercial system in the future, USD 5 per tag and USD 15 per beacon. These costs are very small in comparison with the time and costs saved due to missing equipment.

Data collected:

- Costs associated with lost equipment
- Time it takes to find equipment before and after use case implemented.

Table 12: Results from UC-BSL-3 Asset Tracking

KPI No[3]	Key Performance Indicator	Unit	Pre	Post	Change	Target
6	Cost improvements from improved process monitoring	See below	-	-	85%	25%
14	Reduction in time for optimisation of products/services	Time in minutes	45	10	78%	10%

8.2.2.1 Interpretation of Results

KPI 6: Pre-COMPOSITION – This was a non-existent process. On average, 25% of the equipment due for calibration misses the calibration deadline, because it was missing at the time due to misplacement.

[3] From Table 7

Post-COMPOSITION – After studying the limitations of the technology and adjusting accordingly, all the tracked equipment was always detected. A small percentage of the costs goes towards the tags and beacons and running the system.

KPI 14: Pre-COMPOSITION – The time it takes to find the equipment can vary a lot, from minutes to days.

Post-COMPOSITION – Current time spent is greatly reduced, logging into the COMPOSITION system and finding the equipment takes 5-10 minutes.

8.2.3 Use Case UC-BSL-5 Equipment Monitoring and Line Visualisation

UC-BSL-5 was not fully implemented at the time of writing, and therefore the impact is currently estimations of the outcome when it is fully operational. Both qualitative and quantitative data collection methods are applied.

Automated data transfer will not be available within the project period. However, with every manual data transfer, the system allows a full line visualisation, where it will be easier to see which equipment is free and can be optimised, or where a bottleneck is originating.

Data collected

Qualitative data – A questionnaire inquiring about production time and down-time was distributed prior to the installation of the system, and again after the system had been running for about a month. The questionnaire, shown in Section 12.1 in the Appendix, was completed by three employees, and their responses have been incorporated into the results.

Available quantitative results are listed in Table 14.

Table 13: Dataset for UC-BSL-5

Type	Description	Format	Interval
MES log files	Data for the MES on the shop floor. It contains job order and material description and equipment status on the production line. It also contains several fields providing a detailed description about the line status and production order	Textual data structured as a list of records, one per row. Each row contains an increasing number. The data set is extracted in CSV file format.	From February 2019

Table 14: Results from UC-BSL-5 Equipment Monitoring and Line Visualisation

KPI No[4]	Key Performance Indicator	Unit	Pre	Post	Change	Target
1	Overall reduction in down-time from failures & bottlenecks	Minutes	30	20	33%	15%
4	Reduction in cycle-times from process monitoring & behaviour	-	-	-	No results	10%
6	Cost improvements from improved process monitoring	Same as KPI 1			33%	25%
9	Reduction in scrap and repair costs	-	-	-	No results	50%
14	Reduction in time for optimisation of products/services	Same as KPI 1			33%	10%

[4] From Table 7

8.2.3.1 Interpretation of Results

KPI 1: Pre-COMPOSITION – Login to two different manufacturing management systems, navigate through confusing GUI and create a query to obtain the info from specific machines, then analyse information and decide what action to take.

Post-COMPOSITION – Manual daily file transfer to the cloud, log into the COMPOSITION system, analyse info and decide what action to take.

KPI 4: The system did not run long enough to produce significant results for UC-BSL-5.

KPI 6: Assuming the same performance as in KPI 1, and knowing the time saved will be a direct translation into cost savings, the same improvement percentage will also apply to costs.

KPI 9: The system did not run long enough to produce significant results for UC-BSL-5

KPI 14: System did not run long enough to produce significant results. Assuming the same performance mentioned for KPI 1, the same improvement percentage will also apply to manufacturing optimisation.

8.2.4 Future Steps

For possible future steps, BSL and TNI-UCC are looking into tag size reduction and energy harvesting solutions for UC-BSL-3 and to have wireless sensors for UC-BSL-2.

Although the COMPOSITION platform was only assessed in specific localised use cases within the pilot site, its success already foresees a possible post-project expansion of the platform to other areas/divisions.

8.3 Results from the KLEEMANN Pilot

The KLEEMANN Use Cases cover both intrafactory and interfactory use cases, details of which can be found in *D8.6 Value Chain Pilot II* and *D8.4 Supply Chain Pilot II.* Selected results are collected below.

The results in Table 18 relate to three Use Cases:

UC-KLE-1 Maintenance Decision Support (intrafactory)

Table 15: Dataset for UC-KLE-1

Type	Description	Format	Interval
Vibrometer data	Each vibrometer records acceleration over the three axis (x,y,z), during the operation of the BOSSI machine. The sample rate is 1344 records per second.	The data is transmitted directly through Wi-Fi. It is also propagated by the MQTT message broker to the IIMS components.	Live data since March 2018
CMMS data	Historical data extracted from KLEEMANN's CMMS system and provide information about failures on the BOSSI machine over the years.	Textual data structured as a list of records, one per row. Each row is timestamped.	From 2007 to 2018

UC-KLE-3 Scrap Metal and Recyclable Waste Transportation (intrafactory)

Table 16: Dataset for UC-KLE-3

Type	Description	Format	Interval
Fill-level sensor data	Data is continuously being sent to the BMS. It is described as a percentage indicating the fill level of the scrap metal and recycling bins.	JSON files transmitted through the BMS	Live data since November 2018

UC-KLE-4 Scrap Metal Collection and Bidding Process (interfactory)

Table 17: Dataset for UC-KLE-4

Type	Description	Format	Interval
Fill-level sensor data	Data is continuously being sent to the BMS. It is described as a percentage indicating the fill level of the scrap metal bins.	JSON files transmitted through the BMS	Live data since March 2018

Table 18: Results from the KLEEMANN pilot

KPI No[5]	Key Performance Indicator	Use Case	Unit	Pre	Post	Change	Target
1	Overall reduction in down-time from failures & bottlenecks	UC-KLE-1	Hrs (down-time from failures)	3.5	3	(14%)	15%
2	Cost savings for process monitoring	UC-KLE-1	Euro (Cost of person hours and parts)	1520	960	37%	25%
4	Reduction in cycle-times from process monitoring & behaviour	UC-KLE-4	-	-	-		10%
5	Better interaction with the suppliers, recycling companies	UC-KLE-4	-	-	-		10%
6	Cost improvements from improved process monitoring	UC-KLE-3 UC-KLE-4	L/month (Fuel con-sumption)	260	250	4%	25%
7	Improvement in manufacturing quality	UC-KLE-1	See below	-	-	-	5%

8.3.1 Interpretation of Results

KPI 1: The result is based on 10 years of historical data and 1 year of live data, which unfortunately does not include a statistically significant number of failures. This is indicated by a number in brackets. Another issue is that measuring the vibration amplitude is not sufficient to predict failure of the Bossi machine.

The observed difference is likely not altogether contributable to the implementation of COMPOSITION, and KLEEMANN considers a more realistic expected outcome to be a 5% reduction in down-time with predictive maintenance compared with preventive maintenance.

KPI 2: The result is based on 2 sets of CMMS data. The first set includes the annual cost of person hours and parts related to the polishing machine before the installation of sensors. The second set includes also the annual cost of person hours and parts, but after the installation of sensors and the monitoring of the vibration profile via the COMPOSITION IIMS. Despite the fact that there were no significant failures in the monitoring period, this cost improvement can be attributed to the process monitoring provided by COMPOSITION.

KPI 4: For UC-KLE-4, cycle-time is simply the time between the start and the end of a task, starting with the scrap metal collection and ending with the bidding process and pick up of the scrap metal. The goal is to optimise both the scrap metal collection and the bidding process to achieve better scrap metal prices, minimise costs and receive fast and efficient services. In the pilot, the bidding process was performed by

[5] From Table 7

simulation, i.e., no real numbers are available to support this KPI. However, it is expected that the better interaction with suppliers and the optimised procedures facilitated by the COMPOSITION IIMS will reduce cycle-times.

KPI 5: From the simulation of UC-KLE-4, a better interaction with suppliers related to communication channels, prioritisation of real needs and response time is observed. However, using the application in real-world interactions is needed to evaluate this qualitative KPI**.** A more qualitative approach will be considered, based on KPI No 5 for UC-KLE-4/UC-ELDIA-1.

KPI 6: The forklift's fuel consumption and cost (per month) was reduced by 4%. With the same quantity of recycling materials, this cost improvement can be attributed to COMPOSITION. However, we need more time and evaluations of the application to be more accurate. Also, 5 out of 15 stations are monitored in the central factory. Further improvement is expected in the future if we install the system in all of the recycling bins.

KPI 7: Quality is a very broad concept depending on numerous factors, and therefore difficult to measure. A relatively simplified measurement for UC-KLE-1 could be the number of defects in the piston production line. As for KPI 1, the insufficient amount of live data means that improvement in manufacturing quality presently cannot be attributed to the application of COMPOSITION.

8.4 Results from the ELDIA Pilot

The Use Case is **UC-ELDIA-1** Fill-Level Notification–Contractual Wood and Recycle Materials Management.

Table 19: Results from the ELDIA pilot – UC-ELDIA-1

KPI No[6]	Key Performance Indicator	Unit	Pre	Post	Change	Target
2	Cost savings for process monitoring	seconds	30+	<15	50%	25%
4	Reduction in cycle-times from process monitoring & behaviour	hours	12	8-10	15-25%	10%
5	Better interaction with the suppliers, recycling companies	-	-	-	-	10%
8	Reduction of order-to-delivery time and shipping costs	Cost of logistics process	-	-	-	10%

8.4.1 Interpretation of Results

KPI 2: Savings are measured as cost of time spent on the telephone with customers. Time spent after implementation of COMPOSITION is substantially reduced, and often not even necessary. A gain of up to 50% in time and cost of telephoning is expected.

KPI 4: Reaction time, the time to replace a full container with an empty one, is reduced by up to 25%.

KPI 5: The strength of an already good customer relationship is enhanced due to improved service. This is backed up by the response to a customer questionnaire, see Section 12.2 in the Appendix. Reference is also made to KPI 5 for KLEÈMANN in Section 8.3.1.

KPI 8: Reduction in logistics cost is achieved through more efficient scheduling. Before COMPOSITION, scheduling was organised based on customer calls. With COMPOSITION, fill-level notifications facilitate combination of routes for higher efficiency. Though hard numbers are not available at this stage, a savings surpassing the KPI of 10% is projected.

8.5 UC-ATL-3 Searching for Recommended Solutions

This use case is a partial/concept-only implementation. Information from ATL and NXW is available in the marketplace knowledge base (ontology). The conceptual software solution contains 3 available matching products in the ecosystem, and the agents return the companies matched by the corresponding service and

[6] From Table 7

the product by a ranking order. The associated HMI implementation allows the user to see the dropdown menus for the matchmaking process.

Because this is a concept-only implementation, no real-life results have been obtained.

As mentioned previously, this use case is applicable both for ATL and for NXW.

8.6 Other Results

KPI No. 10 *Number of new, sustainable business models developed in the project* belongs in the area of Improved business and innovative service models.

The target for KPI 10 is 5, which has been achieved and reported previously. *D9.9 Sustainable Business Models for IIMS in Manufacturing Industries* describes and analyses three sustainable business models for the Waste Management Marketplace, the Software Virtual Marketplace and the Supply Chain Marketplace, respectively. Six sub-models, UC-BM-1 through UC-BM-6, were elaborated during the Plenary Meeting in Thessaloniki in June 2018; two of these have been implemented as shown in Table 6.

Furthermore, it was established in *D9.7 Cost, Benefit, and Risk Evaluation* that the COMPOSITION solutions are economically profitable for all pilot partners, both individually and as a whole. The calculations leading to this result will be reviewed and reported in *D9.11 Final Exploitation Strategy and Business Plans*.

8.7 Excluded KPIs

KPI 3 Reduction of amount of non-critical spare parts availability was specifically directed at the sometimes-problematic supply situation in Greece due to the then enforced capital controls. With this situation alleviated, it was deemed unnecessary to include KPI 3 in any of the implemented use cases.

KPI 11 User acceptance ratio of validated ICT security and trust measures was excluded because it was not meaningful in the light of the limited number of end users involved in the evaluation process.

KPI 13 Improvement of non-effective procedures with decentralisation and *KPI 15 Improvement in time-to-market ability* have not been included, because they are not addressed by any of the implemented use cases.

8.8 Comparison of COMPOSITION KPIs with DIGICOR

The four FoF-11-2016 projects DIGICOR, NIMBLE, vf-OS and COMPOSITION have established strong interactions over their lifetime. COMPOSITION pursued collaboration with them also in the evaluation of results. The scope, research areas, types of use cases, evaluation methods and KPIs have been considered, leading to the conclusion that COMPOSITION is closest to the DIGICOR project[7] in this respect.

In particular, thanks to DIGICOR's willingness to share their information and to study our own, it was possible to compare approaches and find similarities. It should be noted that there are no identical KPIs, which is not surprising, since the industrial areas, scope and use cases are not identical, either. However, it was established that both projects have opted to evaluate similar areas/criteria, namely *availability*, *performance*, *quality*, *improved business*, *reductions in expected effort and improved reactions to market changes*. Table 20 shows the indicators that have been identified as being common to COMPOSITION and DIGICOR.

While having different targets, usage scenarios and approaches to evaluation, the two projects are aiming to assess similar issues. Moreover, the impact of the developed tools is expected to affect production and operation in a similar manner.

The following issues have been of key importance to both projects:

<u>*For the Value Chain*</u>

- Increasing availability of resources (equipment and personnel)
- Cost effective process monitoring
- Reduction of time required for the completion of a task
- Improvement in manufacturing quality

[7] https://www.digicor-project.eu

For the Supply Chain

- Assessment of collaborators in the supply chain (suite of products/services, punctuality, reputation of a company, etc.)
- Increase of collaboration
- Increase of trust
- Increase of competitiveness

Table 20: Comparable KPIs in COMPOSITION and DIGICOR

Areas	COMPOSITION KPI	DIGICOR KPI
Improvement from collaborative, real-time efforts towards down-time and logistics inefficiencies (affects **availability**)	Overall reduction in down-time from failures & bottlenecks	I will follow the system's advice if I think that by doing so I will free time to fulfil other work tasks
	Reduction of amount of non-critical spare parts availability	Company profile information, such as past performance results, would allow me to identify the punctuality of a company (e.g. on time deliveries)
Improvement from enhanced integration of manufacturing and logistics processes (affects **performance**)	Reduction in cycle-times from process monitoring & behaviour	For the system to save my time and effort in forming a collaborative team, it needs to have visual aids to guide me in the process
	Cost improvements from improved process monitoring	For the system to save my time and effort in forming a collaborative team, it needs to ensure the quality of the information presented
Improvement in manufacturing quality from modelling, simulation and communication (affects **quality**)	Improvement in manufacturing quality	For the system to save my time and effort in forming a collaborative team, it needs to ensure the quality of the information presented
	Reduction of order-to-delivery time and shipping costs	Knowing the punctuality characteristics of a proposed company helps me to identify the likelihood of successfulness of the tender
Innovative services, models and practices optimising manufacturing and logistics processes Improved **business** and innovative service models)	User acceptance ratio of validated ICT security and trust measures	Using the system would help me to trust the proposed partners
Reductions expected in the efforts for integration or reconfiguration of today's automation systems	Reduction in time for optimisation of products/services	I will follow the system's advice if I think that by doing so our competitiveness will be increased
Improved reaction to market changes using holistic global and local optimisation algorithms	Improvement in time-to-market ability	The system would give me awareness of the capabilities of a company

It is opportune that both COMPOSITION and DIGICOR platforms are part of the eFactory project[8] that aims to create a federated smart factory ecosystem, thus allowing the evolution of the platforms and the joint monitoring of the evaluation of results.

[8] https://www.efactory-project.eu

9 Conclusions

This report is the final evaluation report of the COMPOSITION IIMS Platform that optimises the manufacturing processes by exploiting existing data, knowledge and tools to increase productivity and dynamically adapt to changing market requirements. This is achieved through the connection of supply chain (interfactory) data and services among enterprises and the connection of value chain (intrafactory) data within a factory, so that it can meaningfully support decision-making.

The deliverable describes the effort spent on *Task 8.4 Evaluation According to Specification*, measures the outcome of the project against the user requirements and gives the results obtained for all the use cases at the pilot sites, both interfactory and intrafactory.

As the project progressed many of the use cases included in the first iteration underwent re-evaluation and changes with regard to their importance and impact to the end users. As the list was refined, the use cases were arranged in tiers dependent on priority. All the Tier 1 use cases were fully implemented, and in Tier 2, some were fully implemented while others were concepts and partial implementation. As most of the focus was on these, the Tier 3 use cases were not implemented within the time frame of the project.

For the final cycle of the project, 22 Lessons have been learned, some of which have affected the user requirements, if not in their substance, then in their implementation.

All the presented use cases met the requirements in terms of implementation and deployment. Measuring the outcome of the implemented use cases against the KPIs from the Description of Action, almost all of the use cases met or exceeded the targets.

In Boston Scientific, the three use cases implemented are intrafactory. *UC-BSL-2 Predictive Maintenance*, which was very high priority, gave promising results, meeting or exceeding the targets on the relevant KPIs. With the fan failure prediction and new generated data and analyses, the down-time is optimised and reduced. There will also be cost savings from a reduction in scrap and maintenance cost. For *UC-BSL-3 Asset Tracking*, there was no system in place to track equipment before COMPOSITION, so the results showed great improvements in terms of cost savings and reduction in lost time looking for equipment. With *UC-BSL-5 Equipment Monitoring and Line Visualisation*, the system has not been running long enough to give any significant results for some of the KPIs, although with the full line visualisation, there will be an overall reduction in down-time from seeing where a bottleneck is originating or which equipment can be optimised. For possible future steps, BSL and TNI-UCC are looking into tag size reduction and energy harvesting solutions for UC-BSL-3 and to have wireless sensors for UC-BSL-2.

At KLEEMANN both intrafactory and interfactory use cases were implemented. *UC-KLE-1 Maintenance Decision Support*, which was very high priority, met most of its targets. Despite there being no significant failures in the monitoring period, there is still cost savings for process monitoring and a reduction in down-time. For *UC-KLE-3 Scrap Metal and Recyclable Waste Transportation*, the forklift's fuel consumption and cost were reduced by 4%, with further improvement expected if the system is expanded in the future. For *UC-KLE-4 Scrap Metal Collection and Bidding Process*, the bidding process was performed by simulation and showed expected results, but real-world interactions would be needed for a more quantitative evaluation.

For *UC-ELDIA-1 Fill-Level Notification – Contractual Wood and Recycle Materials Management*, the results were also positive with KPIs exceeding the targets in both cost savings and in time to replace a full container with an empty one.

In summary, the results show the successful implementation and benefits of the COMPOSITION platform, with the technology being used on all the pilot sites functioning well. Although the platform was only assessed in specific localised use cases within the pilot sites, its success already foresees a possible post-project expansion of the platform to other areas/divisions within the pilot partners, as well as future developments based on the COMPOSITION project outcomes.

10 List of Figures and Tables

10.1 Figures

10.2 Tables

11 References

(British Design Council, 2007)	11 lessons: managing design in 11 global brands. https://www.designcouncil.org.uk/resources/report/11-lessons-managing-design-global-brands
(Glenaffric, 2007)	Glenaffric Ltd (2007). *Six Steps to Effective Evaluation: A handbook for programme and project managers*

12 Appendix

12.1 Questionnaire for UC-BSL-5

- Does the line visualisation give a good/accurate overview of the line?
- Is there a reduction in down-time due to early detection of equipment status change?
- Do relevant personnel get appropriate notifications when equipment status changes?
- Is the status in real time?
- Has production time improved?
- Has down-time improved?
- Is it easier/quicker for appropriate person to perform repairs?
- Is down-time prevented by more attentive monitoring of line due to improved visualisation?

12.2 Questionnaire for UC-ELDIA-1

This questionnaire was mailed to 15 of ELDIA's biggest customers:

How supportive would you be to the idea of installing sensors on the containers located at your site, considering the fact that this will improve the replacement time of a full container?

If supportive, would you facilitate us with internet connections, and installation of specialised equipment on your site?

All 15 were very supportive of the idea, and 13 of them answered that they would do anything they could to facilitate us.