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Robotics in Application Areas and Coordination & Support

Flexible Assembly Manufacturing with Human-Robot Collaboration and Digital Twin Models

FELICE

D1.4: Innovation management plan†

Abstract: This deliverable provides information and documents to describe the plan for managing the innovations of the *FELICE* project.

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1.0	30/06/2021	Massimo Di Pardo (CRF)	Final version.

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List of Abbreviations

AWS	Adaptive Work-Station
BMC	Business Model Canvas
CA	Consortium Agreement
GA	Grant Agreement
IMP	Innovation Management Plan
IMS	Innovation Management System
IoT	Internet of Things
IPR	Intellectual Property Right
SoA	State of Art
STA	Scientific Technical Achievements
SWOT	Strenghts Weaknesses Opportunities Threats
TRL	Technology Readiness Level

Executive Summary

This document reports the most important aspects related to the identification of the innovative technologies under development in the FELICE project. The main purpose of innovation management is to ensure that research activities, technological developments and project results are excellent and useful.
The Innovation Management Plan is a public document (PU).

The first part is dedicated to the analysis of the state of art and the possible potential innovation that this project aims to produce in respect to the SoA.
Some innovative results are already visible and of value. A total of 9 innovative assets are identified (list on pag.21 with risk analysis), others have to be planned in the flow of research in development according to an innovation plan.

For the assets identified in this deliverable the analysis of the innovation potential is carried out based on 1) the degree of innovation, 2) the exploitability, and 3) the impact.
In addition, the SWOT analysis is also carried out, which for the moment is focused only on the *FELICE* system as a whole (in which the 9 assets mentioned above are merged), because its further deployment in subsystems will be better defined later. The SWOT chart is reported on page 25.
The deliverable continues by assessing the socio-economic landscape to reach the potential users of the identified technology and innovations, with the aim to further assess the market potential. The market indicates a positive trend for collaborative robotics applications. Therefore, innovations related to Cobots and HR interaction are promising and the *FELICE* system presents excellent opportunities for exploitation. From a social point of view, the *FELICE* system will be able to interact safely with people by adapting to the variability of tasks at each workstation and learning from past interactions. This makes the *FELICE* system particularly innovative in terms of interaction and social aspects.

The second part of the document is focusing on the plan that we want to implement for sustaining the innovation process along the project development and beyond the end of the project. The approach of the document refers to CEN/TS 16555-1 which aims to give guidelines for proper innovation management of organisations.
Based on the above statement this deliverable shows the consortium strategy for fostering innovative results of the *FELICE* project.
The innovation management process is then based on specific actions as follows: mapping potential innovative results, breaking the system down into subgroups that can be exploited standalone, identifying improvement paths and assessing obstacles and barriers to the innovation process including market constraints. All these actions are summarised in a roadmap on page 35. In the final chapters a look at IPR aspects is given with close reference to the contents of the Consortium Agreement content.

In conclusion the continuous monitoring of innovations is recommended by regular updating of the roadmaps and annual discussion of the monitored results. The next checkpoint for innovation results is planned at month 18.

1 Introduction

The *FELICE* project has a very complex structure and aims to identify cutting-edge solutions in the field of collaborative robotics and human-system interaction.

To achieve this result, mobile and interactive robots will be used as well as a self-adaptive workstations to best accommodate the worker.

In addition, an evolved MES system called "orchestrator" will also be developed to manage and coordinate the interactive devices with the needs of the worker and the production system. All these solutions will have to be developed thoroughly and tested in an operational scenario very similar to the real one.

In order to obtain valid results from an innovative and competitive point of view, able to win the race with the main products on the market, a strategy is needed that guides technological and product innovations towards competitive solutions.

In practice, it is necessary to define what we want to sell and what value we want to attribute to the inventions produced. It is clear that in order to pursue the best effective result for improving the state of the art, a strategy and an action plan are necessary to manage the development of the innovations arising from the scientific and technological outcomes of the project. This document contains the description of the strategy and the innovation plan to effectively develop the project.

This document describes the structure and the initial assumptions as well as the activities through which the *FELICE* project will manage the innovation within the project organization, trying to maximize the impact of its results.

To obtain a good result and maximize the impact, the identified innovations are periodically reviewed and subject to revision every six months, according to the guidelines of the European innovation management standard CEN / TS 16555 [1].

Innovation management also connects to the research activities in order to steer the project from a scientific and technological perspective.

This document also reports the activities necessary to protect the intellectual property developed in the project in accordance with the G.A. and the C.A.

1.1 Purpose of the document

The main purpose of innovation management is to ensure that the project's research activities, technological developments and results exceed the state of the art but also that they are linked to external technological developments being competitive with them.
A further objective of innovation management is to identify the most interesting innovative solutions for a potential market. Furthermore, the innovation plan must pursue this objective with a low level of risk for the project, avoiding that the project results lose relevance for the reference markets.
This document describes the strategy adopted to planning the innovation development and the exploitation of innovations. The document is reporting all the main aspects to be considered in the project for the innovation management. In particular focusing on:

- The analysis of the scientific and technological achievements in order to identify the weak points, and possible risks;
- The innovative technologies and products identification;
- The analysis of the evolving socio-economic context (e.g., user needs, market trends, stakeholders and competitors);
- The innovation plan based on actions to be taken for fostering the innovation and to protect IPR of the Project.

This deliverable moreover intends to support a proper innovation management throughout the entire duration of the project, in line with the "Guidelines for Innovation Management" introduced by the European Committee for Standardization (CEN)/ Technical Specification (TS) 16555-1.

The aim of CEN/TS 16555-1 (also CEN/TS or Technical Specification hereafter) is to guide organizations to introduce, develop, and maintain a framework for systematic innovation management practices. The Technical Specification consists of seven parts, however Part 1 "Innovation Management System" (IMS) is relevant within the scope of this report.
According to the CEN/TS, the IMS is composed by some key elements that are:

- Understanding the context of the organization ;
- Establishing the leadership for innovation and strategy;
- Planning for innovation success;
- Identifying and fostering innovation enablers/driving factors;
- Developing an innovation management process;
- Evaluating and improving the performance of the IMS;
- Understanding and using innovation management techniques;

In the following chapters, the key elements of IMS will be included and customized with *FELICE* context and needs, without losing an overall consistency with the Technical Specification.
In fact, considering that CEN/TS is mainly conceived for structured small-medium organisations, some adjustments could be needed to exploit this Specification within *FELICE* (e.g. in terms of leadership, roles and responsibilities that can differ from those usually foreseen for a company).
Therefore, starting from the general IMS key elements (as reported in the CEN/TS), this report will move to the core components of *FELICE* innovation management system.

1.2 Intended readership

The intended readership is considered to be the European Commission, the *FELICE* Project Officer, project partners involved in the *FELICE* consortium, beneficiaries of other Horizon 2020 funded project as well as the general public. The Innovation Management Plan is a public (PU) document.

1.3 Relationship with other *FELICE* WPs and managerial organization

The relationship of this deliverable with other WPs is driven by the development aspects and technical implementation aspects. So that the WPs of main interaction are the following: Work Package 3 related to “System baseline”, Work Package 4 about “Perception mechanism”, Work Package 5 concerning “Cognitive robotics and adaptive workstation”, as well as the Work Package 6 concerning “Data-driven digital twin of production process” and finally the Work Package 7 about “AI for predictive models of human behaviour and production evolution”.

As far as concerns all these Work Packages it is evident the possibility to extract from them some innovative aspects that could be used as they are or by further customisation as specific target products. To some extent, work described here is also linked to Work Package 8 (WP8) as it captures innovations from the *FELICE* pilots, benchmarking, impact analysis and the evaluation of the solution against individual business needs.

Obviously, the strictest relation can be found with Work Package 9 (WP9) because it refers to the exploitation and dissemination of results and it is part of the innovation management objectives. In fact, this WP focuses on the identification of innovative assets and the exploitation of main results arising the project.

All the deliverables coming from these Work Packages are fundamental for the identification of “potential innovation” and to depict gradually the “innovation plan”.

Moreover, an organizational structure should help to foster the connections and the collaboration among the Work Packages and outcomes of the project. In the following the scheme of the organization.

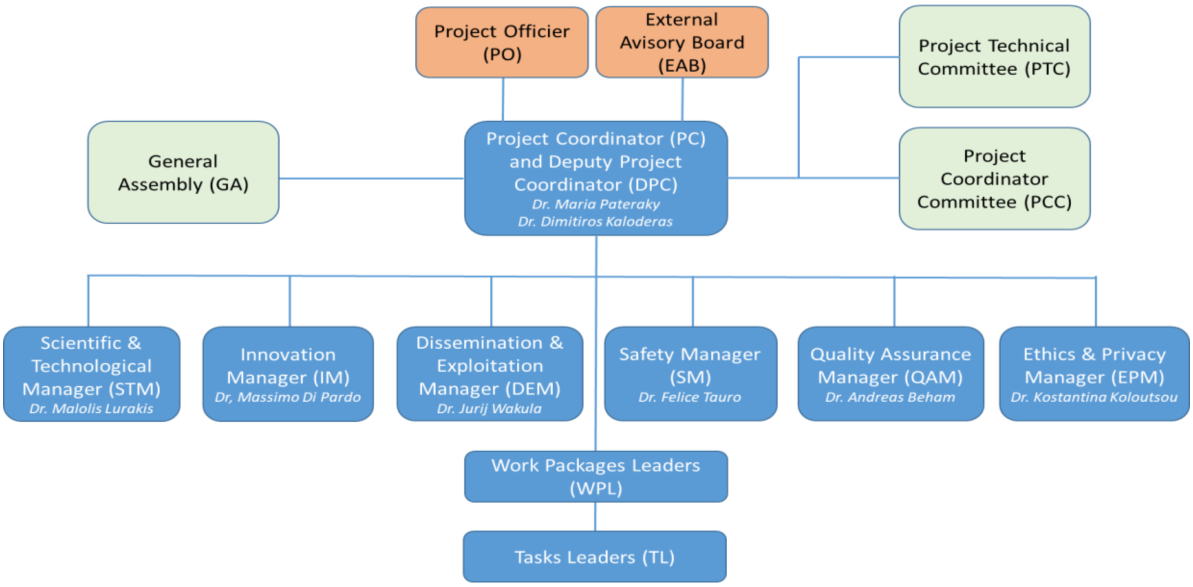

Figure 1: Overview of the management structure, roles, and responsibilities

As reported in the GA *FELICE* is a research project whose mission is innovation. In order to achieve the innovation objectives, the entire project plan and development phases have been defined in line with the project mission. Furthermore, the configuration of the consortium as well as the organisation of the management structure were designed to

best meet the development of the innovation target. The organisational structure also includes the role of the Innovation Manager (IM) that, in collaboration with the project co-ordinator, the Scientific and Technical Project Manager (STM) and finally the Project Co-ordination Committee (PCC), has to manage the innovation process.
The main activities assigned to the indicated managerial group are aimed at constantly supporting the innovation process by using also a decision procedure as described in the GA and shown in the scheme of the figure 2.
The activities will be oriented along three main lines as reported below (from the GA):
• *Platform innovation stemming from enabling technologies that will permit collaborative robots to be integrated in the assembly process, enabling flexibility and agility supporting the "Operator 4.0" paradigm.*
• *Application and Systems innovation stemming from interdisciplinary research combining ergonomics and occupational science, as well as research in collaborative robotics, computer vision, AI and skill based programming into software and hardware innovations integrated in a distributed computing structure forming the FELICE framework.*
• *Service innovation stemming from the deployment of the FELICE framework in simulated assembly line pilots, the procedures and applications developed through this process as well as lessons learned from the adaptation of FELICE to real-world manufacturing environments.*
As described later, in this deliverable, innovative ideas will be systematically collected and selected involving the whole consortium in the context of the relevant WPs. Following the analysis and selection phases, the results obtained will be shared and discussed with the main actors involved in the selected "innovations". During the phases of the innovation process the IM will support the WP leaders a) for the assessment of the coherence of the "innovations" with the project mission and b) about the subsequent possibility of exploitation on the market or in the consortium of the "innovations". The IM will give support also for the management of all issues concerning the IPR.

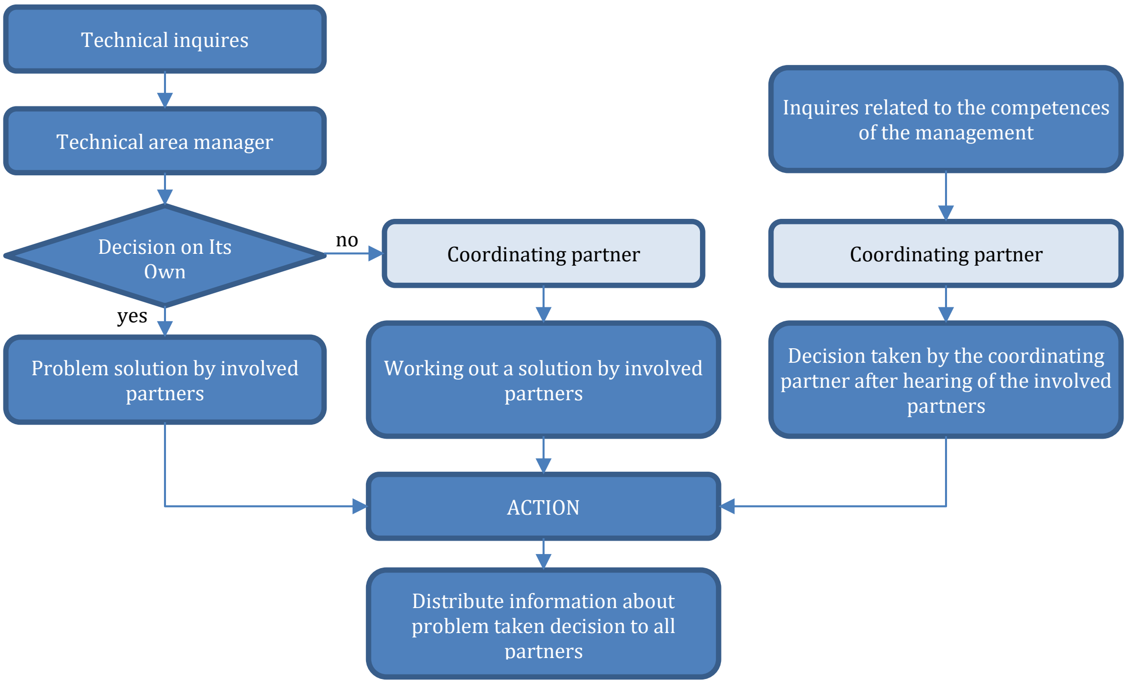

Figure 2: Overview of the decision making procedure

2 Innovation Potential

2.1 State of the Art as a starting point

The partners of the project developed the analysis of the state of art, during the proposal writing.

Based on the suggestions of the European IPR Helpdesk guidelines, an initial situational analysis should be undertaken by the consortium members prior to project start and aims to provide the starting point for innovation potential definition and aspects concerning exploitation activities.

In the following, we report the starting point extract from the GA (for the moment) with the aim to review periodically this part according to the project development timeline.

More updated information will be available in the next period from the Deliverable "State of the art report" (D3.1). On that base, the following analysis (2.2) will be periodically (every 6 months) carried out.

2.2 Advancements to the State-Of-The-Art

In the following paragraphs are reported the main advancement in respect to the current state of art for the topics that will be involved in the *FELICE* project research. These advancements represent a way of thinking about innovative development for products, processes or services. Let's see now the ten advancements of the *scientific and technological aspects* in respect to the SoA:

1. Safety for Human–Robot Interaction:
Incorporation of an intrinsically safe robot design featuring collision detection, light-weight moving robot parts, protective padding, limited robot velocity and maximum energy, transported parts/tools of limited mass, etc. Implementation of collision avoidance mechanisms by using proprioceptive and exteroceptive sensors to regulate the robot's velocity depending on the presence of humans or obstacles in its vicinity.

2. Human Cyber-Physical Production Systems:
Given the novelty of the topic and the urgent need to move towards Human CPPSs, *FELICE* key contributions in symbiotic HRC assembly are:

- Model-based approach for the analysis, (conceptual) design, simulation, verification, and validation of high quality HRC covering the production processes to be performed, the machines and robots, the human operators, the human state and activity trackers as well as the human-machine interfaces, which builds upon and adapts the MACON method, theory, and prototypical tooling;
- Decision Support Service, aimed at studying and predicting the behaviour of the HRC through simulation models monitoring based on real-world data;
- Resiliency Control Service, which aims at modifying the physical systems' parameters in order to withstand potential changes in the environment and still function with the best performances;
- Performance Optimization Service, which compute the best performing combination of the physical systems' parameters (AI Driven Digital Twin) and acts upon the CPPS;

- Bird's Eye View Service, which consists of a virtual real-time representation of the CPPS and allows accessing the asset's status, history, future operations, and expected operations (e.g. routine maintenance); What-if Scenario Configuration Service to define and test 'what-if' scenarios on the virtual assembly stations.

3. Open, scalable and secure IoT infrastructure: *FELICE* will leverage on the open standards-based cloud FIWARE platform specifically built for IoT ecosystems. *FELICE* will take advantage of the Orion Context broker, which retrieves the essential information from the ambient space. *FELICE* will take advantage of built-in Openstack [2] Identity management and Policy Enforcement point (PEP) access control [3]. The *FELICE* dynamic orchestrator either native or incorporated into the basic Fogflow [4] variant will provide an environment to match service objectives versus latency as defined by the user and system context.

4. Robot navigation in dynamic environments: The majority of existing SLAM methods assume a static background.
Clearly, this assumption is not suitable for an assembly setting where workers, workpieces and robots are constantly moving on the shop floor. To deal with moving objects, we aim to integrate motion segmentation techniques into SLAM. Furthermore, to increase the practical applicability of existing SLAM methods, we will build upon them to increase their robustness to challenges such as the lack of sufficient texture and changing illumination.

5. Object detection and 6D pose estimation: We aim to extend state-of-the-art in the 3D sensing of challenging object surfaces in industrial environments by combining different methods on object classification and 6D pose estimation.
We will rely on existing methods on DL to expand recognition categories for industrial tools, considering intra-class and inter-class variability. Tactile exploration will be used along with the use of weak cues (i.e. contours) to resolve lack of information and ambiguities in 3D sensing, as well as, in pose estimation and tracking.

6. Human behavior analysis: For human behavior analysis we aim to exploit information from both static cameras at the workstation, placed at moderate distances from humans as well as cameras on the mobile robot to detect the human poses and actions. Non-visual information will be further exploited aiming to resolve ambiguities in the spatial and temporal domain by considering also non-visual information from wearables (accelerometers).
Furthermore, we aim to combine appearance and motion features, with simpler classifiers and further exploit learned features from data collected during the initial evaluation phase using deep convolutional networks as part of available toolboxes.

7. Task-level programming: The idea of decomposing a certain robotic task into a set of primitive robotic actions has gathered a lot of attention and several tools are commercially available (e.g, Drag&Bot, Artiminds *a*) that allow the user to program the robotic task in this fashion. However, these tools require the action primitive parameters to be known a priori for a successful execution and cannot be easily modified during execution.

Given the dynamic nature of the environment, the action primitive parameters should adapt according to the given situation. The variations could relate to inability to grasp the object due to change in its position (caused by sensor or other disturbances), change in user requirements (e.g., in case of object handover, the robot has to adjust to the height of the user) slippage of object from the gripper during manipulation *FELICE* aims to improve existing task-based programming tools by enabling them to deal with dynamic changes.
The strategy is to build on PRO's existing XRob task-based programming framework [5] and exploit the multimodal (verbal, human tracking, object recognition, gestures) to deal with dynamic changes. Coordination between the XRob tool and the high-level cognitive system in *FELICE* will be the key for achieving this goal.

8. New implicit measures for the design and assessment of HRC: Joint activity with cognitive robots is a form of social interaction in which humans and robots coordinate their actions in time and space, making changes in their environment [6]. It is therefore important to consider the social and motivational aspects of human-robot interaction. While very extensive explicit measures for the assessment of human-robot interaction have been proposed, such as the USUS framework [7], implicit socially and motivational relevant behavioral measures are less considered. Therefore, in the context of *FELICE* explicit assessment criteria as used in the USUS framework are supplemented by implicit behavioral measures. It is assumed that these measures are less biased and therefore better reflect the actual attitudes of the human partner. However, it is important to interpret such measures in the context of validated psychological theories.
The different competences of the *FELICE* consortium allow to combine psychological and occupational science research methods with methods of robotics and artificial intelligence. This interdisciplinary cooperation enables the development of new forms of behavior measurement and interpretation, for example, by drawing conclusions about the affective states of the human partner based on systematic deviations from individual behavior patterns (individual motor signatures [8]) in order to adapt the cooperation behavior of the robot accordingly.

9. Machine learning for embedded industrial applications: Our ambition is twofold. We aim to improve the performance of machine learning algorithms that are promising for this project like Deep/Reinforcement Learning for control and image processing (with applications in predictive maintenance etc.) by applying and improving our previous research on machine learning compiler. Furthermore, with machine learning algorithms applied in production the collected data and experience will help us to improve also the models by adapting them to the specific requirements. As an example, to our best knowledge, Deep Reinforcement Learning was not applied to an industrial process yet but shows good results on physical robots.

10. Skill-based orchestration and adaption in assembly lines: The innovation is based on modelling and directly operating per-product instance-workflows on a new low-footprint and service/skill-oriented SCADA-middleware using OPC-UA. This middleware and its corresponding orchestration tool features on the one hand easy-to-use programming & operating of assembly workflows and on the other hand the potential to fully flexible execute production steps within a manufacturing plant. Together with AI-based optimization algorithms, production workflows may be autonomously and dynamically rescheduled in real-time by changing the assignment of workers (human or robot), work steps to workstations or even the order of work steps. To this end, *FELICE* considers the development of hierarchical plans scheduling complex team behaviors, after considering the temporal characteristics of human-robot interaction at a local and global scale.

2.3 The analysis of the scientific and technological achievements

The analysis of the scientific and technological aspects will be developed during the whole lasting of the project. Some parts are planned as objectives to be achieved, some other aspects could be extracted from the findings and used as technological innovative solutions to be further developed.

Some innovative outcomes are already visible and valuable as reported in the following chapter (2.3.3 Innovative assets), some others must be planned in the streaming of the research in development according to an innovation plan.
In this analysis, we consider Pros and Cons of the project developments starting from the *Innovation Potential defined in the G.A. (section 1.4.2)*.

For the analysis we start from the Scientific and technological achievements declared in the GA in order to detect any further improvement to be considered on these aspects.

To be more precise and critical in this review the following criteria were implemented, which are 1) the degree of innovation, 2) the exploitability, and 3) the impact, as following described:

1) *Degree of innovation* can be defined as how new an innovation is and the gradual difference from the precedent state it has to be measured and evaluated on. When a new product, service or process has been introduced, the degree of innovation is then possible to be assessed in the future. Furthermore, a degree of innovation can also characterize the complexity of an innovation project.
2) *Exploitability* is defined as the degree of exploitation of the solution and its use of available resources.
3) *Impact* can be defined as the positive or negative impact on a social, economic or environmental matter. The assessment is made on the impact that the solutions can have on enterprises' competitiveness.

Revising the advancement of STA with respect to the SoA in this view the following table can be built. For each criteria, three levels were considered (low, medium and high). This approach will be possible also for further detected areas of innovation and for new achievements. The evaluation was carried out by the team of CRF experts in the field of robotics and manufacturing systems.

In addition, this table can be considered as a tool for monitoring the periodically updating of the situation.

Table 1: Analysis of scientific and technological achievements list

Scientific and technological achievements	Degree of innovation	Exploitability	Impact
1. Safety for Human–Robot Interaction	Medium	High	Medium
2. Human Cyber-Physical Production Systems:	High	Low	High
3. Open, scalable and secure IoT infrastructure	Medium	High	Medium
4. Robot navigation in dynamic environments	High	High	High
5. Object detection and 6D pose estimation	High	High	High
6. Human behavior analysis	High	Low	High
7. Task-level programming	Medium	Medium	High
8. New implicit measures for the design and assessment of HRC	High	High	Low
9. Machine learning for embedded industrial applications	High	High	Medium
10. Skill-based orchestration and adaption in assembly lines	High	Medium	High

2.3.1 Further internal and external opportunities for innovations

This section is dedicated to the evaluation of the internal context (synergies of the research group or optimization costs or resources engagement) that could get benefit from the innovation process or that can be influencing the innovation process. On the other hand, this section wants to consider also possible external opportunities coming from new markets or legislation, modification or reorganization of the work methods with related economic advantages. The scientific and technological achievements are analysed in the following table to understand in which way they can influence or can be influenced by the internal and external opportunities.

Table 2: Opportunities for Scientific and technological achievements

Scientific and technological achievements	Internal context	External opportunities
1. Safety for Human–Robot Interaction	Synergy, Internal Standards	Regulations and international standards. New devices IoT.
2. Human Cyber Physical Production Systems:	AR tools and smart assistance systems availability	Technologies integration and highly customized products
3. Open, scalable and secure IoT infrastructure	Existing IoT structures and procedures, Cybersecurity dept.	Centralized IoT operating environment. Blockchain-Based IoT. Extended connectivity.
4. Robot navigation in dynamic environments	Synergy with other projects, Internal Standards	Transversal application to different sectors. Human behaviour modelling.
5. Object detection and 6D pose estimation	Transversal use of results	Sensors development for robust and accurate monocular 6D pose estimation
6. Human behavior analysis	Synergy with other projects, Internal safety standards	Extension to the artificial intelligence application; Transversal application to different sectors.
7. Task-level programming	Transversal use of results, existing robotics task-based programming	New technique for programming and user-friendly visual programming

8. New implicit measures for the design and assessment of HRC	Knowledge and skills synergy at project level and end user level	Regulations and international standards. Cognitive modelling.
9. Machine learning for embedded industrial applications	Synergy with other projects, Internal Standards	Maintenance and intelligent asset management in various industrial sectors
10. Skill-based orchestration and adaption in assembly lines	Knowledge and skills synergy at project level and end user level	Transversal application to different sectors. Real-time condition-based monitoring in industrial environments.

2.3.2 Innovative assets identification

This part of the document focuses on ***technology and product identification*** and description. These technologies are then evaluated (based on assessing criteria) and prioritized considering reliability, weak points and possible risks. *This identification is carried out inside the Scientific and technological achievement about something of concrete that can be sold in short period and represents an asset of the project.* Assets are intended as innovative products or technology evaluated according to the criteria of "maturity level" in percentage and the timeline foresee to achieve the necessary degree of maturity useful for go on the market.
The starting point of this "innovative assets" identification is the assets list already defined and reported in the GA. In the following table, there is a summary of the selected assets that could be exploited after some further development and then that can represent the first step for the Innovation Plan development. The table 3 reports the estimation of the maturity level and the expected market achievement for each asset. The criteria on which these elements were evaluated are based on knowledge developed till now and what is still need to be developed. The time to market is an estimation based on the time necessary to complete the development of each asset before it will become available after the completion of the project. These evaluations were carried out by the group of experts inside the project partnership.

Table 3: exploitable assets list

Asset	Type	Product/Technology description	Maturity level	Market achiev.
1.Digital twin	SW	Graphic simulation tool to support virtual and constructive simulation for complex, immersive 3D virtual scenarios for manufacturing systems	100%	0 years
2.Pervasive scene description	SW	A real time environment monitoring module producing low-level representations by combining info from multiple visual sensors.	75%	1 year
3: Detection and localization of challenging 3D objects	SW	plug-n-play tool for detection and pose estimation of objects with difficult appearance properties, exploiting visual and non-visual cues (tactile) during robot actions	75%	1 year
4: Fluent human-robot interaction	SW	A planner enhancing Human-Robot collaboration fluency by considering action interdependencies, prioritization, and time constraints	75%	1 year
5: Assembly Line Orchestration	SW	A tool that dynamically deploys robots to support human workers, detect and resolve	75%	1-2 years

		errors and improve assembly line performance		
6: Domain Specific Workflow Modelling Language	SW	A language for assembly-task description to provide hierarchical task structures for the dynamic scheduling of the assembly line and task orchestration	75%	1-2 years
7: Human-Robot Interaction Model	SW	Parameter-based model as a tool encompassing socio-cognitive prerequisites for effective interaction and signaling modes for system state.	60%	2-3 years

2.3.3 Extra assets

In the first part of the project, some other aspects were investigated according to the procedure for innovation. An extra asset was identified over the previously mentioned seven software. It is the Adaptive Work-Station (AWS) that include the hardware mechanism for adaptation (actuators and sensors) and sw devices (for Hw control).

By the adaptive workstation, it will be possible to change the configuration of the component allocation to be assembled according to the criteria that the orchestrator will use (mainly for the moment based on the anthropometry of the worker). The adaptation will happen every time the workstation will change position (and work phase) and a new worker will approach it.

Alongside the workstation, there will be a screen for interfacing the worker with the production system including the equipment and the workstation setting.

Table 4: exploitable extra-assets list

Asset	**Type**	**Product/Technology description**	**Maturity level**	**Market achiev.**
8. Adaptive WorkStation (AWS)	HW	Adaptability of the component allocation according to the anthropometry of the worker.	10%	3 years
9. Advanced Interactive Screen (AIS)	HW/SW	Advanced Interactive Screen (AIS) able to connect the worker to the production system (including the orchestrator) and to the AWS	20%	2 years

Also for these two extra assets the adopted evaluation criteria are as above described.

2.3.4 Weak points, and possible risks of the detected innovations

This section focuses on evaluating the identified assets to check the potential risks that can be classified into the following groups (provided in Part A of the GA):

(i) Execution risks;
  a. Partner related;
  b. Planning problems; and
  c. Consortium collaboration issues.

(ii) Technical risks; and

(iii) External risks.
  a. assess the usability of the results in and beyond the context of the project

b. identify the competing technical approaches
c. replication strategies of the project results by third parties

At the end of the project each asset will merge into the final result that will be the *FELICE* System. So the sum of the risks of assets will be found also in the development of the final organic result of the project that is therefore useful to analyse.

For this reason the "***FELICE system***" is considered as a whole and some evaluations can be carried out in terms of risks related to the development in the next three years, as following reported.

Risks are mainly referred to as the technical and external risks because the project, at the beginning of its development, shown low risk due to the partners' weakness (excellence of the partnership) and not significant deviation from initial plan.

As far as collaboration issues among partners, the management organization and the decision making process as described in the paragraph 1.3 should strongly reduce the risk of failure. Anyway the risks are as follows:

Execution risks: In general, this risk could be mainly related to the collaboration among consortium partners rather than to the single partner. In fact, the high competence of the partnership ensures the right knowledge necessary to develop the innovation for the asset on which the partner is more involved.

A small but noticeable risk about execution by each specific partner can be found in the level of available resources really necessary compared to those planned. In fact, the need for resources can increase in function of the difficulties of the technical development in particular for such complex objectives on a long-lasting project.

On the other hand, the collaboration among partners, due to the complexity of the detected innovations, can introduce some lack of connection or overlapping issues.

Technical risks: Despite the high level of competencies of the partners involved in the development and the skills level of the people working on the innovations, a possible risk from a technical point of view is always present due to the possible errors or mismatching in respect to the specification/needs. Failure unforeseen or weakness of prototype system can also occur for the ongoing development.

Of course, the risk is higher for the innovation not yet fully developed and minimal for the innovations with good level of maturity (no risk for the full-developed solution).

External risks: All the innovative developments that are targeted to the *FELICE* system application are also based on the scientific studies of their own field in which many other research groups are striving to found similar products or technical solution for application in the industrial field as well as in other fields like medical or logistics or services.

The risk of a similar approach from competitors' side exists and it is embryonal for assets with a low level of maturity, much higher for assets with high level of maturity.

On the other hand, the time to market for the assets is inversely proportional to the maturity level and this is a competitive advantage.

The following table reports (only as overview) also the estimation of the several mentioned risks carried out asset by asset.

Table 5: Risk analysis for assets list

Asset	Execution risks			Tech. risks	External risks		
	Partner related	Planning problems	Consortium collabor. issues		Usability of the results	Competing approaches	Replication by third parties
1.Digital twin	✓		✓		✓	✓	✓
2.Pervasive scene description	✓		✓	✓	✓		✓
3: Detection and localization of challenging 3D objects	✓		✓	✓		✓	✓
4: Fluent human-robot interaction	✓	✓	✓	✓	✓	✓	
5: Assembly Line Orchestration	✓	✓	✓	✓	✓		✓
6: Domain Specific Workflow Modelling Language	✓	✓	✓	✓	✓		✓
7: Human-Robot Interaction Model	✓	✓	✓	✓	✓		✓
8. Adaptive Work-Station (AWS)	✓		✓	✓		✓	✓
9. Advanced Interactive Screen (AIS)	✓	✓	✓	✓		✓	✓

All the considerations carried out till now in the chapter 2.3.4, as well as the table 5 (synoptic table) that is summarizing the risks estimation for the mentioned assets, are based on the experience of the CRF team in the field of robotics and manufacturing systems.

As already underlined in previous paragraphs, this analysis can become more precise in the next months of project development according to the concretization of the results and the adjustment deriving from the experimentation.

2.3.5 SWOT analysis considering the EU landscape

This section focuses on the *FELICE* system intended as a system that can be implemented on the green field of a medium or big industry plant.

The system as already known is obtained by merging of several sub systems. Despite some subsystems can be evaluated separately because they can be adapted to be used like stand-alone systems they will be evaluated here as integrated into the *FELICE* production systems.

The SWOT analysis for the moment is targeted on the *FELICE* system only because its further deployment into subsystems will be better defined later (in terms of technical details and innovative solutions). In any case the “object” to which we refer is ideally described in the following sketch.

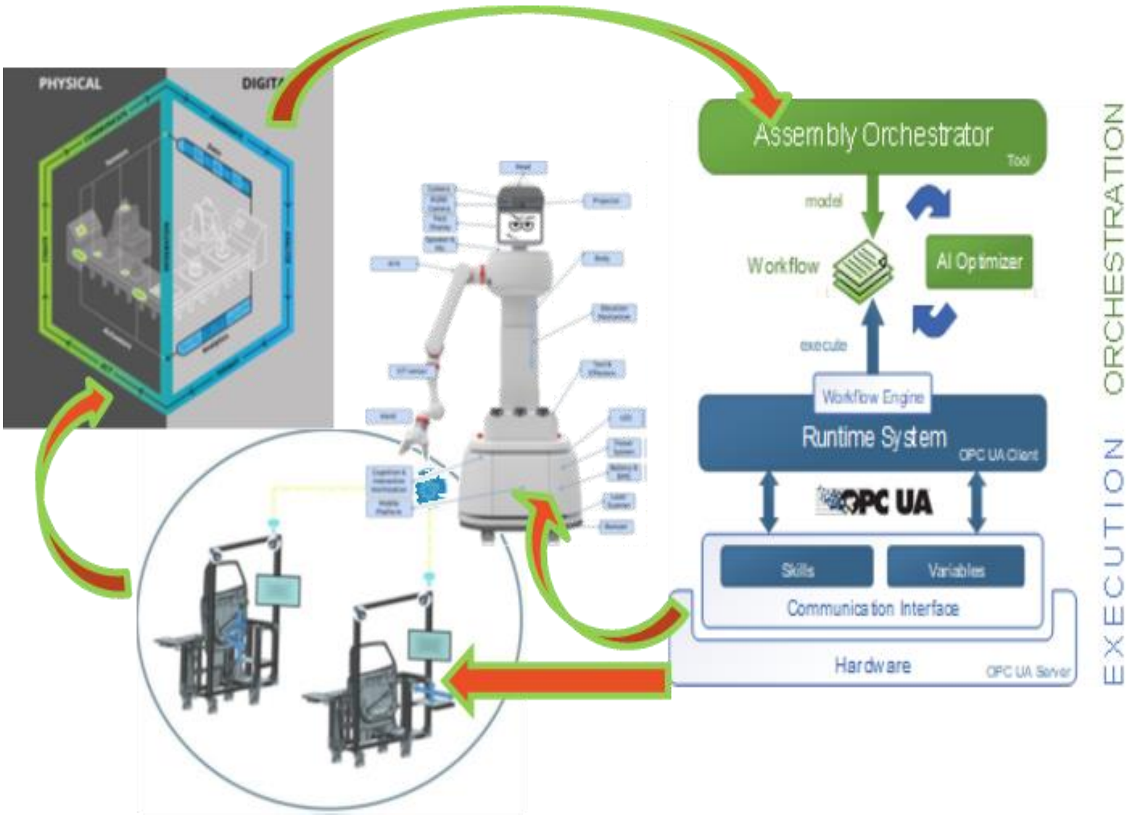

Figure 3: Conceptual sketch of “FELICE system”

SWOT Chart

To compile a SWOT chart some considerations are necessary to understand the allocation of the single elements of the analysis. For this, we start with a description of the four groups of elements and their content.

Strengths: one of the main points of strength is the orchestration that should be able to organize the work activity among workers, mobile robots and workstations. This, together with the management of the production scheduling deriving from customers' requests, gives more evident added value to the system. So the “***orchestration of the***

production” is strongly innovative and represents a good levering for the competitiveness of the whole “*FELICE* system”. On the other side the “***adaptability of the workstation***” to the needs of the worker and the needs of the task represents an innovative concept not yet fully developed in industrial environment. There are several “adaptation” approaches of the workplace, of which at least two are to the task (Twin Trolley System to rotate the car body in production operations) and to the worker (mobile platform for highness compensation), but both adaptation approaches are not concentrated on a single workstation.

Another strength point is the availability of a ***mobile collaborative robot*** for assisting the worker during the operational process. This cobot will be developed to have a constant strict collaboration like another ancillary worker to the operator. This is an advancement in HRI with respect to the current status of the art in industry. The last strength point is the ***digitalization of the process*** that through the digital twin model will enable the decision making of the orchestrator to foresee the best configuration in quasi real-time.

Others positive effects are related to the strong human-robot interaction ***HRI development***, based on cobotics and orchestration and to the ***safety and ergonomics*** improvement of workers due to the ***workload optimization and reduction***. In parallel, there are further advantages concerning ***increasing of efficiency and productivity*** due to the reallocation of the tasks in function of the added value operations that can be concentrated on the worker leaving the not added value operations to the cobot.

Weaknesses: the weak aspects of this system are linked to the ***complexity***. Many different subsystems must work together communicating effectively among them in an efficient way. Complexity does not help the management of such a structure making it sensible to the misalignment and defects.

Moreover, to satisfy the productivity needs the whole system has to be ***interfaced with the existing production systems*** of the plant. This operation also if based on a green field application sometimes include several problems depending from the compatibility of the commercial IoT devices used in the plant and related ***communication protocols***. Not all the plants have standardized IoT.

Another possible weakness of the *FELICE* system could be the ***speed of intervention*** (and problem solution) on demand. On this aspect despite a strict specification, no data are available at the moment and further data will come in the next months following the project development and the experimentation. Because of the required high standard of safety, some ancillary operations need to be carried out following a safety procedure (for instance confirmation of grasping objects from the robot by the operator) that is time consuming. This aspect risks becoming a weakness.

The last weakness detected for the system is related to the still evolving standardization and the ***lacking of harmonized certified procedures*** in the collaborative industrial robotics sector. In this field many regulations and standards already exist (ISO10218-TS 15066) but a complex collaborative structured environment is not yet regulated by standards.

Opportunities: there are many opportunities for such a system depending mainly for the innovative approach under development. The biggest opportunity is ***the modularity of the system*** that can help the deployment of several subsystems to be further developed as stand-alone systems. For example, a mobile robot with vocal interaction able to be included in small or medium industry could represent one of the exploitable assets. Modularity means also adaptability of the system to the needs of the customers.

Among opportunities for further development and innovation there are the studies and the application concerning the ***advanced HMI interface*** and the ***reduction of cognitive workload induced*** by cobotics. These aspects can increase the interest about this field and create a stronger market for cognitive devices not yet fully defined.

Through the application of *FELICE* system concept, also the ***management of the workforce*** becomes easier, in particular, in presence ofseveral ability limitations of the worker due to health problems or aging.

This aspect can create the opportunity to extend the system application to safety and management objectives of companies.

Looking at market drivers, this new concept gives the opportunity of increasing the interest of the ***customization of the workplace*** and the work environment moving production systems toward a realistic "design for all".

Threats: one of the relevant threats is the ***data privacy management*** depending to the environment in which the system wants to work (industry, logistic and services).

The vulnerability aspects related to the use of interconnected equipment and robotics have to be fully faced before any release in order to be compliant with the highest standards of ***security assurance***.

On the other hand, other possible threats are coming from ***the unregulated use of the system*** in a human-robot integrated environment. The abuse of the rules for managing productivity could push the system to replace the decisions of the humans in many activities and tasks creating a bad perception of this technology from the worker's point of view.

Autonomy of the system in decision-making action can lay a dark shadow on the adopted managerial logic and the workforce could obstacle the system to prevent overtaking by the system. Ethics evaluation of the innovation should mitigate the risk but future, yet unknown, applications could be critical.

Another threat could be related to the ***reliability of the components*** gathered on the market at affordable cost. If the standard of the subsystem quality is not the best in class the reliability of "*FELICE* system" could drop down making the system not reliable enough to compete with other similar innovative devices.

Moreover, the wide IPR protection on the topic relating the cobotics and the manufacturing systems in general could create a barrier for the full development of thy complex system.

Despite an active monitoring of the patents on this topic and an exhaustive IPR policy of the project, the unforeseeable impact of competitors' patents in the next 4 years of project lasting has to be considered.

Based on the above considerations in the following table is collected the synoptic picture of the SWOT analysis.

Table 6: SWOT analysis for "FELICE system"

Strengths	✓ orchestration of the production adaptability of the workstation ✓ collaborative and mobile robotics digitalization of the process ✓ HRI development ✓ safety and ergonomics improvement ✓ workload optimization and reduction ✓ increasing of efficiency and productivity	✓ complexity of the system ✓ interfacing with the existing production system ✓ communication protocols among several systems ✓ speed of intervention for effective and efficient support ✓ certified procedures	**Weaknesses**
Opportunities	✓ modularity of the system ✓ advanced HMI interface for not skilled workers ✓ reduction of cognitive workload ✓ easier management of the workforce in case of limitation and aging ✓ customization of the workplace	✓ data privacy management ✓ security assurance ✓ unregulated use of the system and ethics issues ✓ reliability of the components ✓ impact of competitors patents on subsystem and components	**Threats**

2.4 The analysis of the evolving socio-economic context and of the market

This chapter wants to analyse a socio-economic landscape to reach the potential users of the identified technology and innovations, with the aim to further assess the market potential. This analysis conducted at the initial stage of the project can drive the development of some customisation of innovative solutions and try to meet the needs of the market and users.

In order to facilitate this process of adaptation of innovations it was also thought to create a list of technological innovations to be, potentially, customized by the project activities. As in the previous chapters, we start from the technical-scientific innovations already identified for a first list on which to reason in the next months.

This analysis is centered on the perception of the value of the innovations with respect to the needs of the market which derives from the knowledge of the end user of the project. At this stage, surveys with other partners are not yet foreseen, but the BMC set by the participants will be used to draw useful indications. During the course of the project after the first year, it will be evaluated the opportunity to distribute questionnaires to enrich the survey.

The result of the end-user evaluations together with the perception of the business obtained by the BMC of other partners will be reported in a summary table in order to create a reference for the design of the technologies innovation involved in the project and for further improvement of the *FELICE* system.

2.4.1 Market Overview and Target Market Definition

The global collaborative robotics industry market is still on an ***upward trend*** despite the difficult situation in previous months [9] . In fact in the past year, according to IFR's statistics *traditional industrial robot* installations fell in 2019 by 12%, mainly due to the difficult times in the two main customer industries, automotive and electrical/electronics. More specifically, the *collaborative assembly market* maintains a positive growth trend. These market aspects are driving the search for increasingly reliable and innovative solutions *in the field of Cobots*.

Innovations that aim at *flexible automation* are therefore very interesting and can benefit from a potential market that is still growing.

Among these solutions, those that allow an easier use of collaborative systems and a better interaction between man and robot may have a better chance to establish themselves in international markets.

Data are available showing that the ***most active markets are across all application sectors from automotive assembly to food processing***.

The '*FELICE* solution' can be used on a wide range of application cases and can potentially be used in different industrial contexts to improve the production process and make it more efficient and flexible.

As Germany, the Nordic countries and Switzerland are the leaders in this field, the European Union wants to further develop the robotics sector in Europe through numerous projects. IFR evaluates that "A major contraction must be expected in the short run. But in the medium term, this crisis will be a digitalization booster that will create

growth opportunities for the robotics industry worldwide. The long-run perspectives remain excellent."
As it is possible to see from the chart below the automotive is still the main sector for collaborative robotics application.

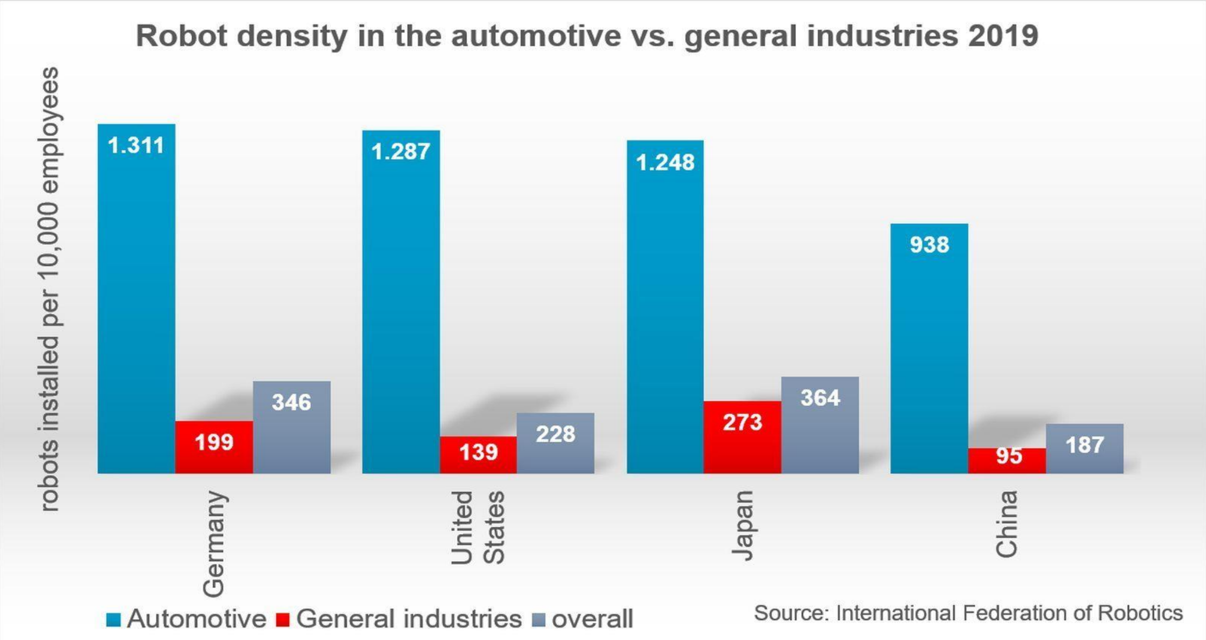

Figure 4: Robot density in industries

Robot sales show a differentiated picture for the major markets within the European Union. Around 20.500 robots were installed in Germany, which remains roughly stable at the 2014 level. Sales in France (+15%), Italy (+13%) and the Netherlands (+8%) were up. Robotics in the UK remains on a low level - new installations have slowed by 16% with around 2.000 units just installed in the UK.
Robot density in the US automotive industry reached a new record high of 1.287 units installed per 10.000 employees. The US is ranked seventh in the world. The density is similar to that of Germany (1.311 units) and Japan (1.248 units). China is in twelfth place with 938 units.

Based on this evaluation the opportunities for the innovative *FELICE* system are very interesting. The first indication focuses on the collaborative environment that seems to be the most promising for the innovations.
The second aspect is concerning the market of reference that is automotive assembly and mechanical processes but applications are interesting for across all sectors. USA, Japan and north Europe are the most promising regional areas.

2.4.2 Worldwide trend in human-robot collaboration [9]

As we have seen in the previous paragraph the market for collaborative robots is basically good, growing globally and if we look at the trend of the last five years it is clearly growing.

The 'sales trend has been in contrast to the general trend with traditional industrial robots in 2019. As already noted as more and more suppliers offer collaborative robots and the range of applications becomes larger. This aspect expands the possibility of creating innovations for the *FELICE* project diversifying the applications and improving customisation.

In addition, the market share has reached 4.8% with a total of 373.000 industrial robots installed in 2019. This is a market that is only in its initial phase and is obviously growing rapidly but ***still has a high potential for growth and expansion***.

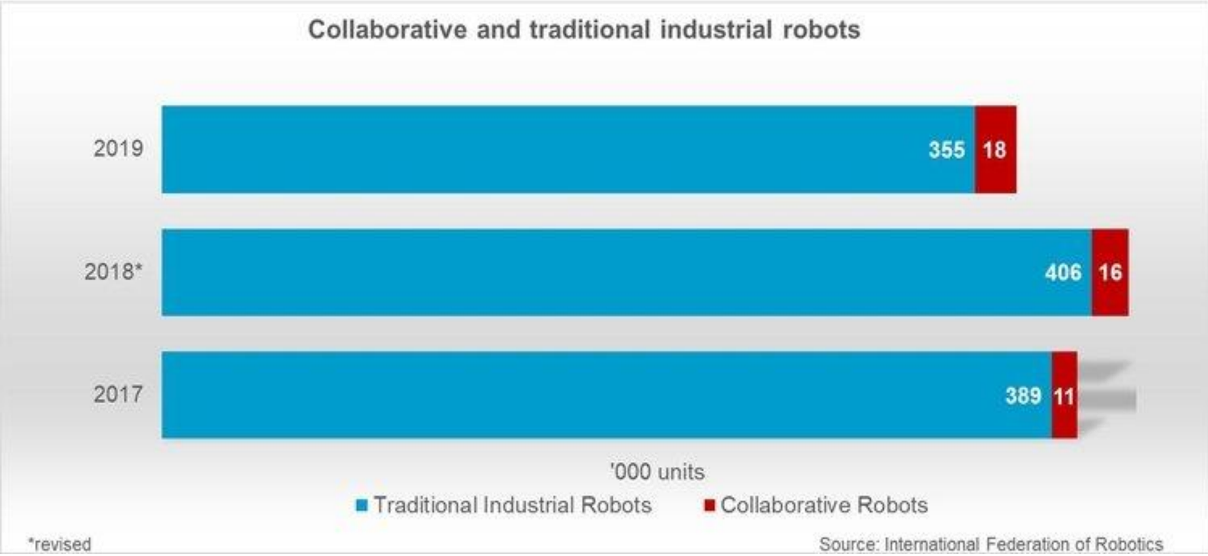

Figure 5: Collaborative and traditional industrial robots

The objectives of robot installations and the expected benefits of industrial robotics in general and cobots in particular still remain the same:

- ✓ rapid production and process efficiency
- ✓ delivery of customised products
- ✓ competitive prices
- ✓ high quality in production

Innovations in this field have expanded the range of industrial robots from traditional robots capable of handling all payloads quickly and accurately but confined to dedicated areas with protective barriers, to new collaborative robots that work safely alongside humans, fully integrated into workbenches.

In this context of market stimuli, the innovations for the “*FELICE* system” can be confirmed with regard to the assets already identified and further possible customisations for applications in sectors other than the automotive sector can also be considered.

2.4.3 Market Analysis of Competitors

Market analysis can be used as a tool to obtain initial feedback on the potential positioning of innovative solutions in the market.
One approach to manage innovation based on its exploitability in a given market is to find big players who already have interests in the specific domain. In fact, these big players already have important marketing and communication channels at their disposal, have a sales and distribution network and already have customers. This approach enabling the market definition and the competitors' detection. In order to identify these potential players, a market analysis is ongoing in parallel to the project development.

The big players are companies that are grouped in three categories:

Suppliers: these are companies that supply components for products similar to ours (intended as Robotic systems and MES) or in the field of collaborative robotics. They have a network of customers that we could address. For example, we could start with customers in the automotive sector.

Integrators: these are companies that already work with robotics and integrate solutions for end customers. The "*FELICE* system" could be a potential value addition to their existing portfolio.

End users: these are companies that have been assessed as potential users of the *FELICE* system.

For the moment is not possible to apply this analysis because too early in the definition of the suppliers and because the system architecture is not completely defined, the detection of integrators is not possible too.

About the end-user some reasoning can be done. The first users (and therefore the first ones interested in the innovations of the project) are obviously some of the partners of the project. It is useful to investigate the way for these users to exploit the innovation and how they could approach the market.

Table 7 –Assets positioning

Asset	Users application	Markets of reference
1.Digital twin	• Production management and process monitoring • Logistics control • Energy Management • Virtual commissioning	• Manufacturing Systems Industry • Manufacturing systems and industry with complex production processes • Companies that carry R&D activities
2.Pervasive scene description	• Mobile Robotics management • Transportation and logistics • Environment Monitoring	• Distributed Computing • Mobile Computing • Location Computing • Mobile Networking • Context-Aware Computing
3: Detection and localization of challenging 3D objects	• Assembling process automation • Industrial and robotics manipulation • Logistics management	• Home automation • Food industry • Appliance industry • Electrical/electronic parts of motor vehicles
4: Fluent human-robot interaction	• Cobotics for assembling • Handling operations for palletizing	• Metal products • Motor vehicles, motor vehicle engines and bodies

	• Wearable robotics for manual material handling • Soft automation for Machine tending for other processes • Manipulation and maintenance tending	• Parts and accessories for motor vehicles • Medical, precision and optical instruments • Household/ domestic appliances
5: Assembly Line Orchestration	• Assembling process automation • Industrial and collaborative robotics for assembling and manipulation • Assembling components management	• Manufacture of cars, trucks, buses and their engines, • Manufacture of bodies for motor vehicles • Manufacture of trailers and semitrailers
6: Domain Specific Workflow Modelling Language	• Heavy construction machinery management • Cobotics management for assembling operations • Mobile Robotics management • Transportation and logistics piloting	• Medical, precision and optical instruments • Household/ domestic appliances • Manufacture of cars, trucks, buses and their engines, • Manufacture of bodies for motor vehicles
7: Human-Robot Interaction Model	• Cobotics for assembling • Handling operations for palletizing • Wearable robotics for manual material handling • Soft automation for Machine tending for other processes • Manipulation and maintenance tending	• Metal products • Motor vehicles, motor vehicle engines and bodies • Parts and accessories for motor vehicles • Medical, precision and optical instruments • Household/ domestic appliances
8. Adaptive workStation (AWS)	• Controller supplier (e.g. B&R, LINAK, or own development) • Assembling process manual and hybrid • Ergonomic and efficient workbench • Flexible and adaptable workplaces • Customized workstations	• Standard part suppliers (e.g. Bosch, Item,) • Actuator suppliers (e.g. LINAK) • Illumination system supplier (e.g. Bosch) • Sensor suppliers (e.g. Pepperl & Fuchs) • Motor vehicles, motor vehicle engines and bodies • Household/ domestic appliances
9. Advanced Interactive Screen (AIS)	• Interactive workplaces • Process management • Quality check and control operations	• Manufacturing systems and industry with complex production processes • Automotive assembly industries

2.4.4 Social aspects

The social aspects of the *FELICE* system are among the main objectives of the innovation under study. Indeed, this innovation is based on 'socially cooperative human-robot interaction'.

In fact, the system will allow the mobile robot to navigate the workshop from one worker to another and to assist workers in their assigned tasks by supporting collaborative assembly.

Since everything has to take place in a context of safety and well-being of the workers, the system also provides for extensive sensorization of the working environment.

A global system will be developed to manage the information coming from the sensors and decide on global parameters such as the speed of the assembly line, the assignment of tasks and the dispatch of robots.

Innovations with a social objective also include tools to describe workflows regarding the interaction between man and robot, and decisions will be made dynamically with respect to workloads and tasks.

In addition, a further innovation to improve worker well-being and workplace ergonomics is the development of adaptive workstations. These workstations are designed to optimally support workers and maintain the ergonomics of the workstation under changing working conditions.

One example is the interpretation of physical expression in terms of acceptance, trust or fear [10, 11, and 12]. Innovative elements incorporated into the *FELICE* system also include behavioural measures implied by social and motivational psychology to assess the quality of human-robot cooperation [13, 14, and 15].

Expectations, fears, stress and well-being are reflected in the motor behaviour for static and dynamic distance control therefore the design considers both the characteristics of the robot (e.g. appearance, behaviour) and the characteristics of the human partner (e.g. experience, gender, age) because they influence the parameters of human distance control.

One of the assets is fundamentally aimed at improving the psychosocial and interaction aspects. In fact, in the *FELICE* system, implicit behavioural measures complement explicit evaluation criteria such as those used in the USUS framework (framework for Human-Robot Collaboration with humanoid robots addressing usability, social acceptance, user experience, and societal impact).

The *FELICE* consortium with its multidisciplinary expertise (psychology, occupational science, robotics and artificial intelligence) is developing new ways of measuring and interpreting human behaviour in order to adapt the robot's cooperation behaviour accordingly.

This development work results in the innovation of core technologies for human-robot interaction including collaborative support in working environments.

Innovative technologies are incorporated into the *FELICE* system to overcome uncertainty in dealing with the complexity of the dynamic environment, (including human behaviour, tasks and workpieces), while ensuring safety and ergonomics in collaborative human-robot assembly.

Innovations from the operational point of view are provided by robots with higher-level skills. It will be able:

1. To pass the necessary tools to workers,
2. To navigate in complex environments,
3. To engage in human-friendly interactions and human assistance.

Management innovations are provided by an intelligent assembly line ('AI-driven MES') capable of:

- ✓ adapt the configuration of workstations to improve ergonomics,
- ✓ perform corrective actions to improve the quality of the assembly process.

In practice, the *FELICE* system will be able to interact safely with people by adapting to the variability of tasks at each workstation and learning from past interactions;

This makes the *FELICE* system particularly innovative in terms of interaction and social aspects.

Furthermore, as mentioned above, the collaborative aspects and the interaction of humans with robotics are an element of competitiveness of products with intelligent automation.

3 Innovation management Plan

This section is finalised to describe the process for managing the innovation across the project development in agreement with the standard CEN / TS 16555.

3.1 *FELICE* Innovation Process

Innovation is the use of new knowledge to develop a new product or service that customers want. It is invention plus its commercialisation [16]. Innovation has also been defined as "the adoption of ideas that are new to the adopting organisation".

Identifying the needs of customers or the market or the company can be seen as the first step in guiding any innovation.

To identify potential innovative ideas, a precise understanding of market needs and opportunities is therefore a crucial step. Also for European Commission, innovation is generated not only through research and technology development, but also through new marketing and management solutions**Error! Reference source not found.**.

Innovative ideas, however, cannot be separated from the strategic and competitive context of a company or project aimed at developing a new solution as in the case of the *FELICE* project.

In fact, even for the innovations already under development for the *FELICE* project, as well as the possible innovations that will be identified during the next months of project development, it is necessary to proceed through a logical flow of actions to optimise the new ideas according to their exploitation and market positioning.

It is therefore necessary to set up a process capable of guiding innovation in order to adapt it to the needs of the market or customer.

The innovation process can be separated into phases.

1 Conceptual analysis
This step is a continuous analysis of the project development in order to select ideas able to be transformed into an innovative solution useful for the market and for target customers. A selection of ideas most promising and consistent with the project mission follows.

2 Innovation Opportunities
The step aims to scan suppliers, customers, competitors, complementary innovators, related industries, research laboratories, universities worldwide. This can be done by partners using their traditional network, by specialized literature, congresses, magazines and other dissemination channels.

3 Identifying Capabilities
Once a new idea or invention has been spotted and the potentiality of innovations as well as its applications are understood, the consortium has to determine three things:

(1) what types of capabilities are required to exploit the innovation;
(2) its capabilities to exploit or to pursue the innovation; and
(3) potential competitors' capabilities.

4 Innovation Strategy
The consortium also determines whether it will follow an offensive innovation strategy in which it will be the first to introduce the innovation by prioritising speed of development or whether it will follow a moderate strategy in which the development aims above all at giving the best results (also from a scientific point of view) and risks not being the first on the market. Which of these strategies it follows is a function of its capabilities and strategic intent.

5 Functional Strategies
The consortium must allocate resources and direct the different functions along its value chain in accordance with these business and innovation strategies.

6 Processes of development
This includes development and testing of the solutions. Management must be able to monitor performance of working groups, functions and organization setup in some agreed upon and understood way. It must establish systems whereby information will flow in the shortest possible time to the right targets for decision making.

The illustrated process can be seen as a scheme of the innovation process in the figure below (figure 6).

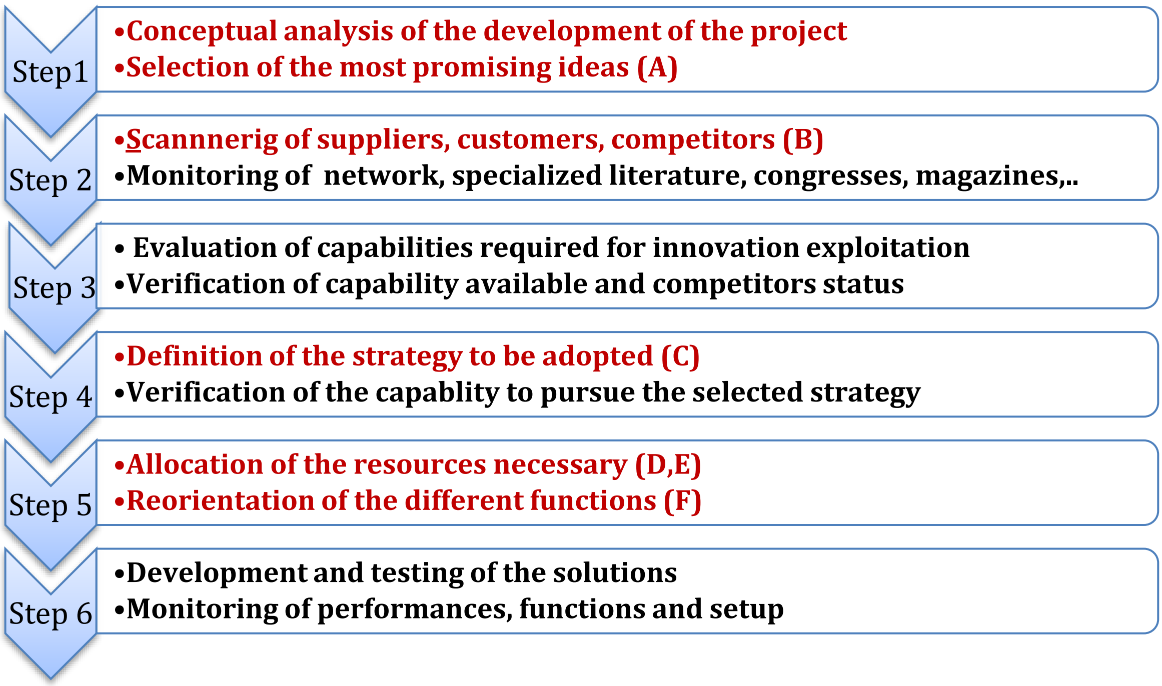

Figure 6: Phases of an ideal-typical Innovation Process

Figure 6 reports some substeps marked in red and identified by a letter. These substeps produce actions used for the innovation plan as better described in section 3.2

3.1.1 Innovation classification

Four types of innovation are essentially defined **Error! Reference source not found.** which group innovations into product, process, marketing, and organizational; *FELICE* focuses mostly on the 1st type of innovation, namely product and service innovation, as it is mainly committed to delivering novel technical solutions for optimizing production process as well as supporting workers wellbeing.

3.2 Management of Innovation plan

As seen in the previous paragraph, innovation can be considered as a process that produces a result consistent with the project's mission. This innovation process which is periodic and interactive must therefore be managed through a plan.

A plan means a list of actions with a logical sequence.

Deploying actions on a timeline means to produce a roadmap. This is discussed in detail in the next section.

In fact, during the innovation process some partial results can be transformed into targeted actions, which in a logical sequence represent the innovation development plan for the *FELICE* project.

For the sake of convenience some important sub-steps of the process have been identified with a letter (A, B, C, E, F) which is also found in the innovation plan for identifying actions deriving from these sub-steps.

Thus, ***the innovation plan for FELICE*** is based on the following ***actions***:

A. Perform a characterisation/*mapping of potential valuable and exploitable results*, i.e. identify different types of results and their potential user groups – on partner and/or consortium level.

B. By *dividing the FELICE system into several technologies*, we increase the potential of *finding potential customers* and getting the system deployed in additional real-life scenarios.

C. Identify the most appropriate *improvement routes* for the innovative results corresponding to the transformation of results into products/technologies exploitable for their target users.

D. Reflect on *potential barriers/obstacles*, and how to overcome them.

E. Identify any *further conditions for market deployment*, i.e. financial investments, regulatory affairs, business development, marketing.

F. Upgrade annually the road maps to capture and assess exploitation opportunities in the project.

Furthermore the activities related to this plan, as well as the final result of the project have to ensure that the exploitation of the FELICE system covers all aspects of the IPR guidelines.

The IPR Management is described in the Section 2.27 of the G.A. and in the Task 9.2 and these rules are used for the management of innovation activities.

3.2.1 Roadmap/strategic plan toward the expected impacts

The Roadmap is a method for the implementation of activities during the course of the project which includes a set of different activities. Although concrete measures are planned and fixed, the strategy will be subject to continuous review and updating in order to react accordingly to upcoming needs, opportunities and conditions.

The roadmap developed at early stage of the *FELICE* project constitutes the layout of the project's strategy for innovation and promoting the project, its approach and results.

It aims to maximise the impact of *FELICE* through technology development, transfer and diffusion. The deployment on the timeline of the roadmap is in agreement with project's Gantt.

While the Gantt described in GA will serve as a guide for the related activities throughout the project and reference of the performed activities against the initial plan, the road map will be used as a template for constant evolvement and updating of the innovation plan itself as the project evolves.

In order to ensure a coherent and purposeful promotion, a dedicated set of measures are planned and will be carried out in the framework of the work-package 9 (WP9 – Dissemination, Exploitation, long term sustainability).

Therefore, the planned activities will be linked to the above mentioned areas either through accompanying observation of IP rights to prevent premature disclosure and IPR infringement or through activities that directly aim at results exploitation.

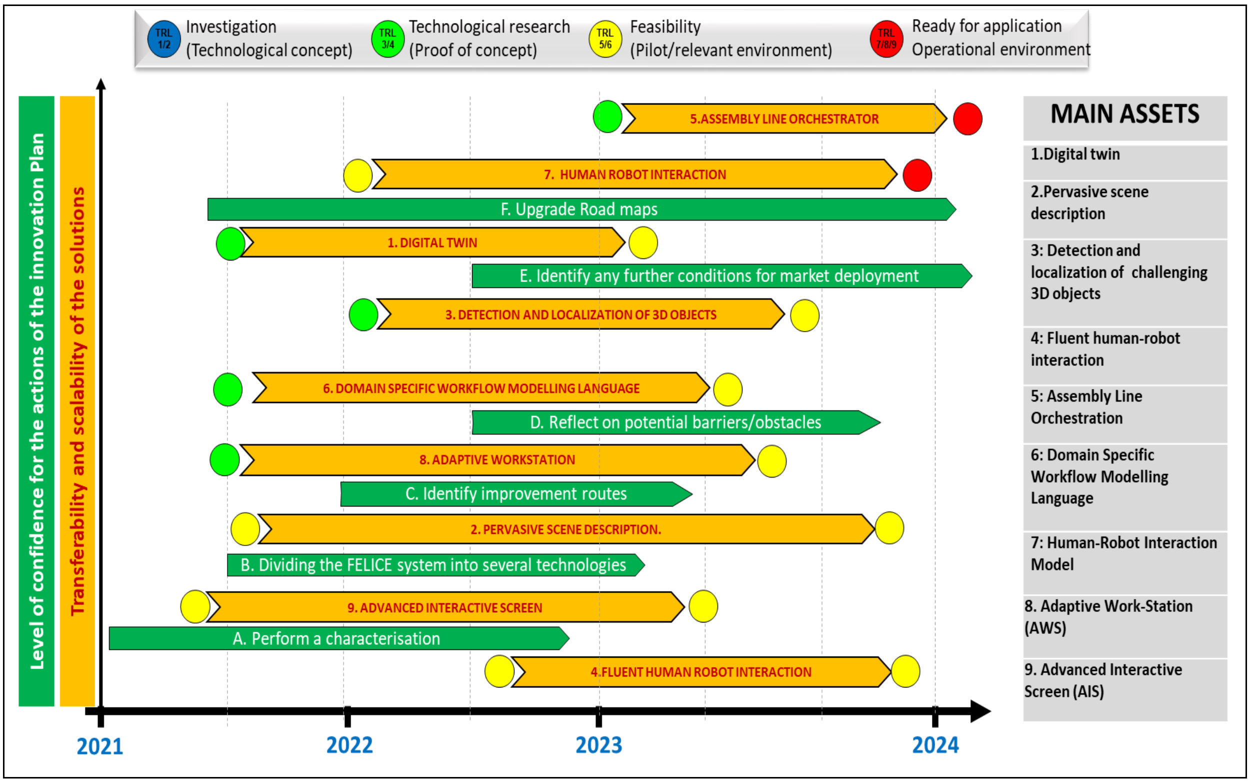

Figure 7: Innovation Roadmap of FELICE project for facing research challenges

3.2.2 Develop future collaboration between the consortium partners

For future collaborations, the idea is to foster the creation of a new subgroup inside the project dedicated to the development of specific systems or sub-systems. For instance more than one partner is aggregating for the development of the robotic hardware, while another group is focusing on the development of the software for managing the orchestrator. In this perspective, the detection of the strongest relationship of collaboration among sub group of partners could be essential for the long-term sustainability of the results of the project and can give the start for new ideas and products.

For fostering this collaboration a set of dedicated meetings is getting place and a dedicated channels information exchange has been also arranged. Further actions in this direction to reinforce the strong collaboration among partners will be defined later in the project according to the concretization of results.

3.2.3 EU robotics Digital Innovation Hubs (DIHs).

The aim is to take advantage of Digital Innovation Hubs which are one-stop shops that help companies to become more competitive in their business/production processes, products or services using digital technologies.

To do this, the partners most involved with the digital developments of the *FELICE* system will be able to engage with the latest knowledge, skills and technologies to pilot, test and experiment with project innovations. Through contacts with DIH participants (universities, industry associations, chambers of commerce, incubators/accelerators, regional development agencies and even governments) a deeper commercial understanding of the potential of the *FELICE* system will also be sought.

3.3 Safeguarding IPR that are created within the project

This section is dedicated to the guidelines for intellectual property creation, to ensure a consistent and transparent protection process.

First, some general considerations on IPR are presented, including important concepts that need to be clearly defined and distinguished. Then, IPR concerning the *FELICE* project and its results are described.

Within the content of the CA, several definitions are included and that are crucial to be considered in this deliverable.

Background: means information and/or knowledge which is held by a Parties prior to their accession to the Consortium Agreement, as well as copyrights or other IPRs pertaining to such information and/or knowledge, the application that has been filed before their accession to this Consortium Agreement, and which is needed for carry out the Project or for Using the Foreground.

Controlled License Terms: means terms in any licence that require that the use, copying, modification and/or distribution of Software or another copyright work (“Work”) and/or of any copyright that is a modified version of or is a derivative work of such work (in each case, "Derivative Work") be subject, in whole or in part, to one of more of the following:

a) (where the Work or Derivative Work is Software) that the Soure Code be made available as of right to any third party on request, whether royalty free or not;
b) that permission to create modified version or derivative works of the Work or Derivative Work be granted to any third party;
c) that a royalty-free license relating to the Work or Derivative Work be granted to any third party.

Foreground: means the results, including information, whether or not they can be protected which are generated by the Project. Such results include rights related to copyright; design rights; patent rights; plant variety rights; or similar forms of protection.

Intellectual Property Rights (IPR): means patent, patent applications and other statutory rights in interventions; copyrights (including without limitation copyrights in Software); registered design rights, applications for registered design rights, unregistered design rights and other statutory rights in designs and other similar or equivalent forms of statutory protection, wherever in the world arising or available; but excluding rights in Confidential Information or trade secrets.

Sideground: means information, other than Foreground developed or otherwise acquired by a Party after entering into the CA, as well as copyright or other IPRs pertaining to such information, and that is introduced into the Project by that Party for use in execution of the Project.

Starting from the set-up described in the Grant Agreement (GA) some more aspects will be considered.

The GA reports that each participant, who contributes intellectual property to the project or has developed intellectual property within the project, must make a declaration about its IPR to the coordinator.

This declaration shall include any special requirements for the use of this IPR in addition to or in derogation of the standard rules on rights in the Consortium Agreement.

Confidentiality and exploitation issues shall be determined at the start of the project and reflected in the Consortium Agreement.

In particular, the following commercial issues shall be addressed:

(i) confidentiality of information disclosed by the parties during the development of the project;

(ii) ownership of the results resulting from the execution of the project;

(iii) legal protection of the results through patent rights;

(iv) commercial use of the results, taking into account also the joint ownership of the results;

(v) patents, know-how and information concerning the use of knowledge, owned by either party, resulting from work carried out prior to the agreement;

(vi) sub-licensing of commercial offers to third parties within clearly defined limits;

(vii) availability of information, products, results, etc., for other EU-funded projects; and

(viii) liability exclusion rules.

As far as concerns the background of the project the CA is regulating the IPR of this part of knowledge and the Attachement 1 is reporting the declared owner for this part.

Anything not identified in Attachment 1 shall not be the object of Access Right obligations regarding Background.
In the section 9.2 of the CA is also reported "Any Party may add further own Background to Attachment 1 during the Project by written notice to the other Parties. However, approval of the General Assembly is needed should a Party wish to modify or withdraw its Background in Attachment 1".

Foreground shall be owned by the Party who carried out the work generating the Foreground, or on whose behalf such work was carried out.

Dissemination, use of knowledge and results generated in the project is governed by the terms of the Consortium Agreement.

In order to make sure that these terms are followed, to avoid disputes and to facilitate business planning, an IPR Directory is going to be kept and updated throughout the lifetime of the project.

The IPR directory presents the IPR rules accepted by all partners at the beginning of the project and that can influence the options for future exploitation and commercialization of the results.

This document listed all items of knowledge relating to the work of the project (results developed in the project), and make explicit for each item:

- The owner(s).
- The nature of the knowledge, and its perceived potential for exploitation.
- The currently agreed status of the item concerning access rights, plans to use the knowledge in exploitation, or plans to disseminate it outside the Consortium.
- Measures required, or in place, to ensure protection of IPR for the item.

Table 8 –Initial version of IPR directory

Partner (owner)	The nature of the knowledge	IPR	Deliverable
ICCS	Concept, methods and software implementation for object detection and tracking	According to the CA	D4.1 D4.2 D4.3
CRF	Methodologies for process testing and optimization	No IPR necessary	D8.4
FHOOE	Algorithms, software architecture, and software libraries	Only in combination with physical device (e.g. adaptive workstation) possible, opportunities for joint patents will be explored	D7.3
PRO	Concept, software implementation for online skill parametrization of robot actions, including robot arm movement and grasping; Software Implementation of online robot task verification	According to the Consortium Agreement	D5.2, D5.4 and D5.5

3.4 Reliability of innovation process

There are five key business objectives for a good exploration process of innovative solutions such as:

1. Continuous innovation to deliver on current customer requirements
2. Product adaptability to deliver on future customer requirements
3. Reduced delivery schedules to meet market windows and improve return on investment (ROI)
4. People and process adaptability to respond rapidly to product and business change
5. Reliable results to support business growth and profitability

In this section, we will analyse the current innovation process against these five aspects.

From this point of view, the *FELICE* project is well-positioned because it responds satisfactorily to the five reliability checkpoints.

With reference to point 1 on continuous innovation, the project itself by its very nature is aimed at obtaining an innovation that will continue for all the years of the project's duration.

Moreover, the innovation process described above is an iterative and interactive process and therefore foresees a continuous monitoring and research of innovative solutions exploitable on the market.

With reference to point 2 on adaptability of the product to future customer needs, the *FELICE* system being developed will be implemented in an automotive plant of which one of the partners, CRF, is the end-user.

The system is designed to adapt to the structure and production organisation of the project's end user as well as to the production system of other companies in the industrial sector (including non-automotive companies).

The use case that will be developed in parallel at FHOOE has the objective of generalising the concept in the development phase in order to draw from it the universal elements useful for adaptation to applications other than the one under consideration.

With regard to point 3, on the reduction of delivery times, one of the objectives of the *FELICE* system is to optimise the work cycle with a specific development section dedicated to improving productivity.

This also implies a better response in terms of delivery times, which the system, being more efficient, will be able to reduce. On the *FELICE* project side, the innovation process with the Road mapping phase ensures proper time management and helps reduce the delivery time of innovative ideas.

As a matter of fact, since a continuous process has been set up, it is able to optimise both the information flow and the decision-making processes concerning the innovations that can be selected and brought to the market.

With reference to point 4, on the adaptability of people and processes to change, the people involved in the design and development phases of the project are by extraction highly competent and qualified and therefore oriented towards flexibility and versatility.

The company partners also provide staff from the research and innovation departments who have a strong aptitude for adaptation and for dealing with new and non-predetermined situations.

Furthermore, the managerial organisation in charge of the innovation process has the mission to identify every possible solution to respond to possible needs and related changes in products or business.

With reference to point 5, reliable results for profitability, the innovation process as it has been structured aims precisely at making a selection of ideas concerning technologies and possible products in order to pursue only those with a high degree of reliability.

Furthermore, the development, prototyping and testing phases considered by the *FELICE* innovation process guarantee the verification of the prototypes' performance in order to ensure their feasibility by identifying the best path to optimise reliability as well.

For the sake of synthesis and clarity, a summary table is given with a three-value rating scale: a + means sufficiently reliable ++ fairly reliable +++ very reliable.

Table 9 –Initial version of Reliability ranking

INNOVATION PROCESS RELIABILITY RANKING	
1. Continuous innovation to deliver on current customer requirements	+++
2. Product adaptability to deliver on future customer requirements	+++
3. Reduced delivery schedules to meet market windows and improve return on investment (ROI)	++

4. People and process adaptability to respond rapidly to product and business change	+++
5. Reliable results to support business growth and profitability	+

4 Conclusions

This document provides a vision of the innovation process and how some assets mentioned in the GA can be used to increase the innovation potential of the project. It provides useful guidelines to identify a common framework able to guide the project to implement systematic innovation, facilitate innovation assessment and benchmarking, and finally detect the market for innovation reference.

Innovation management is however a very complex process that must also affect the mind-set of the working group to allow all ideas that emerge during the project to be analysed and eventually selected.

The evaluation criteria for the selection of the ideas as described are based on the possibility of their use and exploitation on the market, but also scientifically relevant and innovative ideas (not directly linked to the market) can be valorised through scientific publications that will be mainly edited by the university partners.

The innovation management process will continuously monitor the project results and technical developments trying to orient and guide the results towards business and market opportunities.

This non-static process includes periodic joint evaluations of the partners and the innovation manager to refine the process and to identify new ideas or monitor the evolution of those already selected. The innovation plan as well as the roadmap will be frequently updated.

The respect of this plan, together with the achievement of its specific and verifiable objectives, will be a main parameter to measure the final success of the project.

In the coming months, the consortium partners will participate in further innovation evaluations on an annual basis.

The first results of the innovation monitoring will be discussed at M18 for further work.

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