Human-AI Teaming Platform for Maintaining and Evolving AI Systems in Manufacturing

D9.4 First reporting period report

Deliverable Lead	SOFTWARE COMPETENCE CENTER HAGENBERG GMBH (SCCH)
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List of contents

List of Figures

List of Tables

1 Explanation of the work carried out by the beneficiaries and Overview of the progress

This deliverable D9.4 First reporting period report belongs to WP9 Coordination and documents the progress of each work package and the activities carried out to meet the objectives of the Teaming.AI project, risks, contingency measures, next steps and resources used. It also contains an explanation on how the Consortium has followed the Project Officer & experts recommendations taken out of M9 technical review carried out online on the 21st of October 2021.

1.1 Objectives

This section presents the specific objectives for the Teaming.AI project and shows the degree of fulfillment based on the work carried out towards the achievement of each objective in the WPs (see details in the description of work done in each work package). The progress shown monitors from M1 (January 2021) to M18 (June 2022).

Objectives	Progress[1]	Work done in
A: Auditable Ethics Model	**75%**	**WP1, WP3, WP5**
B: Agile Development for Overall Labor Effectiveness (OLE)	**85%**	**WP1, WP2, WP3**
C. Operational Performance by Cross-Functional Teamwork for Overall Equipment Effectiveness (OEE)	**65%**	**WP2, WP3, WP4**
D. Wide Scope of Applicability	**35%**	**WP5, WP6**
E. Exploitation and Replication	**25%**	**WP8**
F. Dissemination and Communication	**50%**	**WP8**
G. Proof of Concept	**30%**	**WP5, WP6, WP7**

Progress towards the achievement of the Teaming.AI objectives is consistent with work package progress as reported by WP leaders. The progress shown monitors from M1 (January 2021) to M18 (June 2022).

Work Package	Progress[2]	Lead
1: Requirements and Prerequisites	**100%**	**PRO**

[1] Progress is estimated based on the weighted completion status of the assigned tasks. The weighting is based on the PM effort of the WP the task is assigned to.
[2] Progress as estimated by work package leaders.

2: Knowledge Graph	**74%**	**WU**
3: Teaming Model	**81%**	**UMA**
4: Machine Learning	**49%**	**ITU**
5: Teaming.AI Engine (Software Platform)	**44%**	**SCCH**
6: Technology Integration	**6%**	**IDK**
7: Proof of Concept	**23%**	**TYR**
8: Dissemination and Exploitation	**50%**	**CORE**
9: Coordination	**50%**	**SCCH**
10: Ethics Requirements	**100%**	**SCCH**

1.2 Project Overview

The Teaming.AI project has started in January 2021 and is expected to end in December 2023 (duration 36 months). In the **first 18 months**, the consortium has achieved some of the desired results. Nevertheless, there is still much work to be done to reach the final goals of Teaming.AI. Figure 1 presents the Gantt chart for the Teaming.AI project, which highlights the current progress circled in red. Actual extension of tasks in “dark green” as discussed with PO.

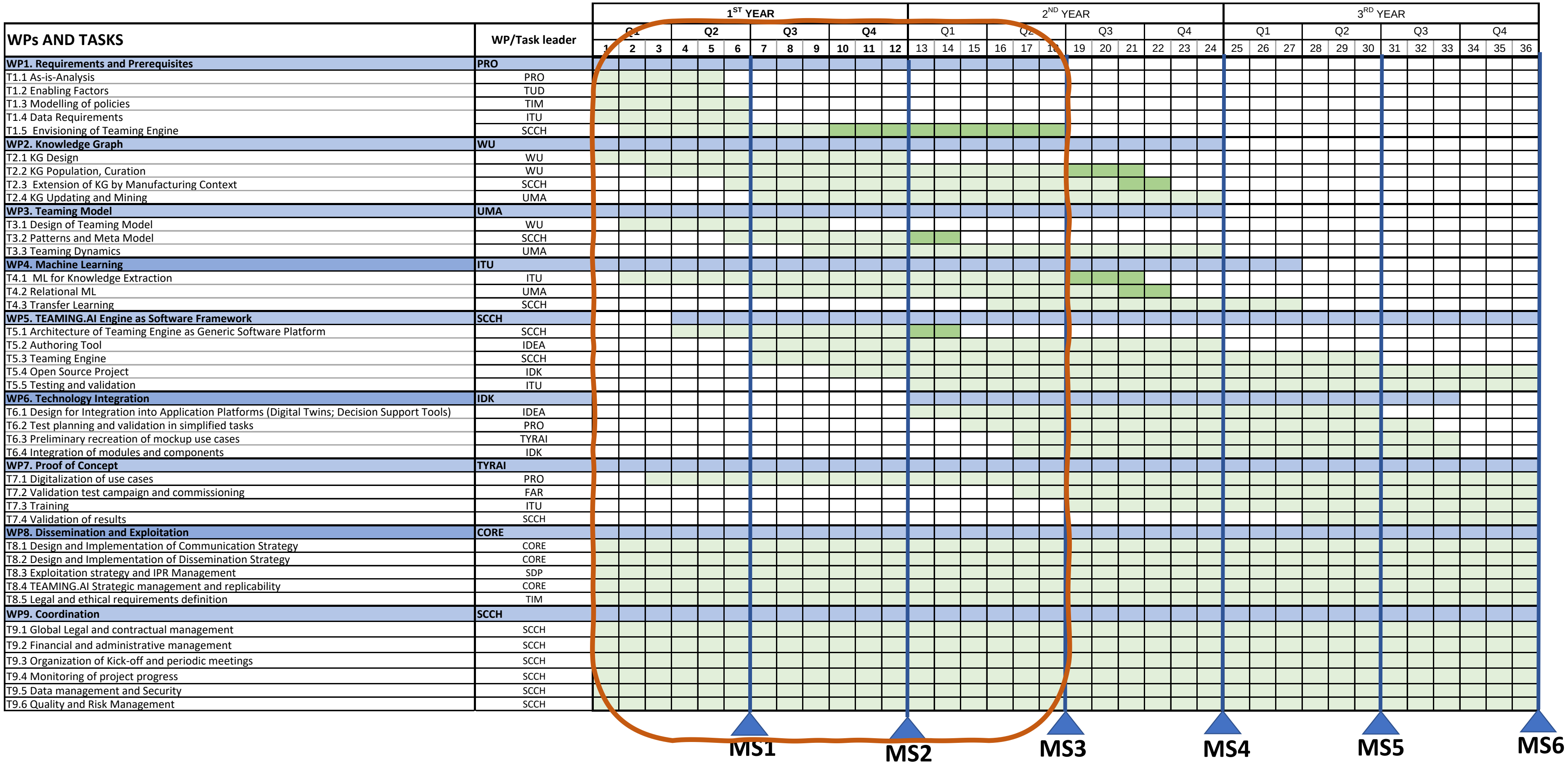

Figure 1. Gantt chart.

It is noticeable from the Gantt chart that the Teaming.AI project has achieved its first two milestones (MS1 & MS2). The achievement of these milestones indicates that Teaming.AI has already concluded the MS1 Requirement and Envisioning of Teaming Engine and the MS2 Design of KG and Software Architecture is completed.

Table 1 reports the list of milestones updated with an explanation on the current status. Similarly, Table 2 reports the list of deliverables with an explanation of their status at M18.

Table 1. Milestones status.

MS No	WP	Milestone	Leader	Means of verification	DD	Status	Comments
MS1	1	Requirement and Envisioning of Teaming Engine	PRO	Requirement analysis and field survey completed	M6	Achieved	Deliverables D1.1 Analysis report on human-AI teaming variants, D1.2 Catalogue of key performance indicators, D1.3 Teaming.AI policies and D1.4 Data requirements report have been submitted, after completing the requirements analysis and the field survey. D1.5 Envisioning Report has been uploaded on M9 as requested by PO on the 19th of April 2021.
MS2	3,5	Design of KG and Software Architecture	WU	Design of KG and analysis based on test data completed	M12	Achieved	Software architecture and Teaming model initial versions defined, Knowledge Graph in progress. Overall ca. 70% progress. D3.1 Teaming.AI model finished and submitted.
MS3	2,4,5	KG Population and Updating	UMA	Laboratory prototype of KG population and updating services	M18	In progress	Slightly delayed, expected to be achieved by M21
MS4	2,5	Authoring Tool	IDEA	Software for Authoring released and validated by user group	M24	Started	
MS5	5,6,7	Teaming Engine and Integration	SCCH	Software for Teaming Engine released by user group; data quality for use case validated and integration in KG completed	M30	Not started	
MS6	5,6,7	Proof of Concept and Open Source Software	IDK	Proof of Concept for all 3 use cases completed; launch as open-source project in LF AI platform; first community building measures completed	M36	Not started	

Table 2. Deliverables status

No	WP	Title	Lead	DD	Type	Status	Comments
D8.1	8	TEAMING.AI Coorporate Identity	CORE	M3	Report	Approved	01/12/2021
D9.1	9	Governance structure, communication flow and methods	SCCH	M3	Report	Approved	01/12/2021
D9.2	9	Data Management and Security Plan	SCCH	M3	ORDP	Approved	01/12/2021
D9.3	9	Quality assurance Plan	SCCH	M3	Report	Approved	01/12/2021
D10.1	10	H- Requirement No 1	IAL	M3	Ethics	Approved	01/12/2021
D1.1	1	Analysis report on human-AI teaming variants	PRO	M5	Report	Approved	01/12/2021
D1.2	1	Catalogue of key performance indicators	TU Dublin	M5	Report	Approved	01/12/2021
D1.3	1	TEAMING.AI policies	TIM	M6	Report	Approved	01/12/2021
D1.4	1	Data requirements report	ITU	M6	Report	Approved	01/12/2021
D8.2	8	Communication and Dissemination Master Plan (CDMP)	CORE	M6	ORDP	Approved	01/12/2021
D1.5	1	Envisioning report	SCCH	M9	Report	Submitted	Modified and completed after M9 Tech. Review. Resubmitted on M18
D3.1	3	Teaming Model	WU	M9	Other	Approved	01/12/2021
D2.1	2	KG Design	WU	M12	Report	Submitted	30/12/2021
D3.2	3	Teaming Model Initialization	SCCH	M12	Other	Submitted	28/02/2022
D5.1	5	Software Architecture	SCCH	M12	Report	Submitted	28/02/2022
D2.2	2	KG Population Methodology	WU	M18	Report	In progress	Delayed M21 (September 2022)[3]
D4.1	4	ML Driven Knowledge Extraction	ITU	M18	Other	In progress	Delayed M21 (September 2022)
D8.3	8	First Report on Dissemination activities	CORE	M18	Report	Submitted	30/06/2022
D8.5	8	Market análisis	SDP	M18	Report	Submitted	30/06/2022
D8.8	8	Preliminary Exploitation Strategies and IPR Management	SDP	M18	Report	Submitted	30/06/2022

[3] As discussed with PO. Same case for D4.1, D7.1, D2.3, D4.2 and D7.2.

D9.4	9	First reporting period report	SCCH	M18	Other	Submitted	30/06/2022

No	WP	Title	Lead	DD	Type	Status	Comments
D7.1	7	Use Case Digitalization	PRO	M19	Demo	In progress	Delayed M22 (October 2022)
D2.3	2	Industrial KG	SCCH	M20	Other	In progress	Delayed M23 (November 2022)
D4.2	4	ML Driven KG based Recommendation Systems	UMA	M20	Other	In progress	Delayed M22 (October 2022)
D7.2	7	Use Case Commissioning	FAR	M21	Demo	Not started	Delayed M24 (December 2022)
D2.4	2	KG Updating Methodology	UMA	M24	Report	Not started	
D3.3	3	Teaming Model Dynamics	UMA	M24	Other	Not started	
D5.2	5	Authoring Layer	IDEA	M24	Other	Not started	
D8.6	8	Business models and Business Plan	SDP	M24	Report	Not started	
D4.3	4	Transfer Learning	SCCH	M27	Report	Not started	
D5.3	5	Teaming Engine Layer	SCCH	M30	Other	Not started	
D6.1	6	Integration Design	IDEA	M30	Report	Not started	
D8.4	8	Second Report on Dissemination activities	CORE	M30	Report	Not started	
D6.2	6	Test Management Process	PRO	M32	Report	Not started	
D6.3	6	Mockup Use Cases	TYR	M33	Report	Not started	
D6.4	6	TEAMING.AI integration platform	IDK	M33	Other	Not started	
D5.4	5	Open Source platform	IDK	M36	Other	Not started	
D5.5	5	Test and validation results	ITU	M36	Report	Not started	
D7.3	7	Use Case Training	ITU	M36	Website	Not started	
D7.4	7	Use Case Validation	SCCH	M36	Report	Not started	
D8.7	8	Updated Business models and Business Plan	SDP	M36	Report	Not started	
D8.9	8	Plan for Exploitation and IPR management	SDP	M36	Report	Not started	
D8.10	8	Legal and ethical requirements report	TIM	M36	Report	Not started	
D9.5	9	Second reporting period report	SCCH	M36	Report	Not started	
D9.6	9	Final report	SCCH	M36	Report	Not started	

1.2.1 Risk Management

Under the scope of WP9 (Coordination), the management of the risks related to the project is performed. The following table contains the risks detected, analyzed and reviewed until month 18 (June 2022).

Table 3. Risk status.

Nr	Description of risk	WP Number	Proposed risk-mitigation measures	Comments	Probability [low, med, high]	Impact [low, med, high]
1	Communication and coordination problems	WP1, WP10, WP2, WP3, WP4, WP5, WP6, WP7, WP8, WP9	By a project management structure, defined procedures and the experience of the partners.	Despite COVID situation, and initial difficulties a sound communication has been built.	low	high
3	Delay in deliverables deadlines or achieving milestones	WP1, WP10, WP2, WP3, WP4, WP5, WP6, WP7, WP8, WP9	The progress of the project will be continuously monitored by WP leaders and PC and any detected issues will be faced with corrective measures.	• Coordination monthly meetings and Steering Committee every two months established. • ~~D5.1 delayed to M18~~ • ~~D3.2 delayed to M14~~ • ~~D5.3 will be delayed to M14, see #22~~ • D2.2, D4.1 -> M21 • D7.1, D4.2 -> M22 • D2.3 -> M23 • D7.2 -> M24	high	med
4	Workload and/or costs underestimated	WP1, WP10, WP2, WP3, WP4, WP5, WP6, WP7, WP8, WP9	A reallocation of resources in other WPs will be evaluated.	6-month progress report implemented for every partner	med	med

5	Unforeseen scientific or technological impact	WP1, WP10, WP2, WP3, WP4, WP5, WP6, WP7, WP8, WP9	A SAB will be formed during the first six months of the project. Nevertheless, as in any research work, unforeseen scientific or technological needs could appear during the execution of the project. The new needs will be solved on an inter-project basis by a modification of a work package and/or milestone. In this case, the European Commission will be informed via email which will seek its approval.	Steering Committee every two months established, where any impact should be commented, as well as in General Assemblies.	low	high
8	Insufficient match between trust model and human acceptance	WP3, WP4, WP5, WP6, WP7	The match will be highly context dependent, which will be studied by empirical test cases to identify criteria that allow the development of a meta model of trust to gain insight under which circumstances the trust model is trustful; second, the policy for the specific application will be extended to cover also the situation of mismatch, i.e., if there is no sufficient information available to ensure trust, then the policy clarifies how to precede.		med	high
10	Inability to handle high update frequencies in knowledge graph	WP2, WP4, WP7	The modelling depth of the knowledge graph is a direct handle to control the update frequencies (less details -> less updates), so that the update frequencies can be directly controlled. From a research perspective, techniques such as layered knowledge graphs, partial and/or lazy materialization are explored early in the project to facilitate large update frequencies from the very beginning.		low	med

11	The datasets used to train the ML models may contain insufficient, incomplete, not - formatted or faulty data.	WP1, WP4, WP6, WP7	Data assets used to build the predictive models (WP4) for the different use-cases will be available in early stages of the project (T1.4) so that curation, imputation of missing data and processing techniques will be performed to achieve data alignment, to set the data ready to be used in the proofs of concept (WP6, WP7). In addition, enriched expert data will help to add value in cases where not enough production data is given.		low	high
12	Integration issues due to interoperability issues between different components	WP2, WP3, WP4, WP5, WP6	The framework abstraction layer has been designed as an architectural pattern to mitigate integration issues. This layer will be developed following continuous integration methodology. T6.4 will deal with the whole Integration of modules and components and technical WPs include individual test activities. Furthermore, a test and integration plan will be defined early in the project		med	med
13	Novel services do not create value for users	WP2, WP3, WP4, WP5	To ensure an interesting portfolio of innovative services, during the real tests; user feedback would be gathered to improve them.		low	high
14	Not achieving a cost-effective solution	WP5, WP6, WP7	To reduce this risk, all the partners must be aware of the market prices and control costs on their solutions.		med	med
15	Partner not interested in developing its novel services as business core	WP7, WP8	Through communication and dissemination actions, stakeholders interested in developing these novel services will be found.		low	high
18	Delays in gathering data	WP7	Finding alternative data sources	Due to a busy production schedule, there could be some delays in gathering specific data. -> caused delays, see #3	med	med
19	Machine malfunctions	WP7	Implementing additional maintenance checks	Malfunctioning machines could cause a delay.	low	high

20	Injection machine sensorization delays by HW supply	WP7	Advancing data gathering pipeline integration in parallel until have the machine ready.	This delay causes some delays in the data gathering process in order to set up the digitalization of the UC.	high	high
21	Limited access to real-world data from the use cases due to COVID related reasons	WP2, WP3, WP4	WP2/T2.1: Focus on UC1 (Farplas) for guiding data example. WP2/T2.2: Contingency plan in case of persistent data availability issues: proxy use cases. WP3: use publicly available datasets as benchmarks for evaluating the developed methods. Negatively influenced Task 3.3. WP4: actively looking for external/synthetic datasets for similar problems. Expected data provision will be solved during next period.	Should be mitigated until October 2022	high	high
22	Additional work on Requirements Engineering causes delays	WP5	• T5.3 will be delayed up until M14 • Postponement of development activities in T5.2, T5.4, and T5.5 until finalization of the requirements engineering phase in M18. • Parts of the development activities related to T5.3 can be conducted parallel to the requirements engineering phase from M12-M18. • parallel to the requirements engineering phase from M12-M18.	functional requirements and the required scope of the framework abstraction layer (T5.4) is not yet clear, implementation partners of T5.3 and T5.4 are unable to proceed with development activities as planned.	high	high
23	Risk of partners not responding to the dissemination plan and therefore not reaching project KPIs (submission of publications, participation in events etc).	WP8		There are no deviations from Gantt Chart of the project so far.	med	high
27	Values of human dependent KPIs might not be fully defined	ALL	Discussed in SC Meeting		low	high

29	The concrete responsibilities of the different partners related to the implementation of the Teaming.AI platform in general, seems unclear. This does not only relate to WP5, but also its relations to down- and upstream WPs.	WP5 and others	Set meetings to clarify issues, e.g. an implementation-focused bi-weekly meeting.	Bi-weekly Meetings are initiated.	High	High
30	Interaction between Task T5.2 work and WP6 and UC efforts to sparse.	WP5	T5.2 work needs to be tighter coordinated with WP6/WP7	Meetings scheduled for this.	high	high
31	Scope of WP6 tasks have to be adjusted	WP6	Coordination between WP5, WP6 and WP7 is necessary in order to refine the scope of WP6 tasks and propose possible delays.	Meetings are ongoing	High	high
32	Integration of relational machine learning models does not lead to the desired improvements	WP3, WP4	Relational ML could be still useful for the generation of possible explanations of graph-based predictions.		med	med
33	No significant improvements in ML model performance after fusing the models with KG information	WP2, WP4	Reassessment needed how KGs are going to be useful in the context of ML models in UCs.	Method group meeting used for resolvement	med	high
34	Lack of balance across genders in the researcher team	WP10	Opportunities for joining the project will be done strictly on the basis of expertise and needs in specific fields of knowledge, providing equal opportunities to any person that can fulfill the needs of this field, independently of gender, origins, societal position, etc.	In practice, the application of these criteria can result in gender imbalance in the team, due to educational and career biases, limiting the availability of qualified non-male researchers. The TEAMING.AI team frequently assesses gender balance awareness across all partners, to	med	Low

				ensure that non-male researchers with appropriate qualifications are given due opportunities.		
35	Motivation and ability to benefit from project results is not the same for all genders.	WP10	To provide access to the results of this project with no distinction of a person´s gender or other aspects, samples of workers to request their collaboration will be wide and balanced in gender aspects.	In practice, the workforce composition is a limiting factor. However, an argument could be made that TEAMING.AI actually mitigates this problem: by reducing physical strain and injury risks, TEAMING.AI can increase workforce participation by non-males in a traditionally male dominated work environment. This shows that Teaming.AI wishes to actively promote the participation of all genders in AI and in industry.	High	High
Solved Risks						
2	~~Lack of collaboration or withdrawal of the agents involved~~	~~WP1, WP10, WP2, WP3, WP4, WP5, WP6, WP7, WP8, WP9~~	~~Reassign work to other partners if possible or propose the Inclusion of another partner to the European Commission.~~	~~Regular technical meetings established for information exchange. A responsible person assigned for every use case, to monitor closely the progress.~~	~~low~~	~~high~~
6	~~Implementation problems in Use cases~~	~~WP7~~	~~TYRAI will act as technical manager for the implementation in the 3 use cases and each of the use cases will have a responsible for the particular implementation: ITU for FAR, TYRAI for IAL and IDK for GOI.~~	~~UC1: currently too less data, see #18~~ ~~UC2: Sensor installation problem will be fixed 22/01~~ ~~UC3: See #16~~ This risk has been split in several individual risks, see #16, #18, #20	~~high~~	~~med~~
7	~~Ethical viability for Scenarios 3 on physiological data collection~~	~~WP3, WP4, WP5, WP6~~	~~The team involved in Scenario 3 has already filed approval for the scenario setting and the filed approval for the scenario setting and the involvement of voluntary participants to collect physiological data on the human performance and clarifying to them their use for the AI algorithm being deployed.~~	~~Changed to low as ethical approval is on its way (22/02).~~	~~Med~~ ~~low~~	~~high~~

9	Insufficient quality of raw data	WP2, WP4, WP7	The usage of data cleaning methods – both on the raw data as well as the resulting knowledge graph – will be explored and applied. Especially for the latter, UMA has relevant expertise. For the demonstrators, manual data cleaning is applied for rapid advancement and prevention of slowing down other WPs	Now covered by #11	low	high
16	Camera hardware not available for recordings in UC3	WP7, WP6, WP4	Currently developing algorithms on free datasets. Trying to order other cameras in parallel and take the ones which are faster delivered.	Camera Hardware finally arrived in 22/01, re-plan of Spain visit is full in progress.	high	high
17	Partners not reaching KPIs mentioned in agreement (publications, ...)		Now in #23	TODO for all: send list to Ilia	high	high
24	There was some discussion due to the fact that data protection compliance is driven by a specific legal basis (legitimate interest rather than consent) under data protection law, in order to protect the interests and rights of employees	ALL	This has required some rebalancing and restructuring of the compliance approach, focusing less on consent and more on procedural safeguards and consultation of workers' representatives. This approach was found sufficient thus far, and had been foreseen during the drafting of D10.1, so contingencies were in place	-	med	low
25	Communication between partners is not running smoothly due to a lack of face to face meetings but also due to delays in the development of a reference design.	ALL	To foster the collaboration a series of face to face meeting with subsets of partners are planned. First to happen in Vienna, second at Goimek, and third with all partners at one of the Use Case providers. -	-	high	high
26	Requirements engineering takes more effort than planned because of requested alignment with ISO norms. However, there are many vague aspects of teaming and trust that are	ALL	Since this is the research question we want to address during the full period of the project, the requested requirements engineering in this direction can only be limited. To resolve this issue we plan to conduct several iterations of the RE		high	high

	~~difficult to formalize and thus also to specify in form of a verifiable requirement.~~		~~during the runtime of the project to better reflect this issue~~			
28	~~Reduced coordination activities due to Requirements Engineering~~	~~WP5~~	~~Due to unforeseen amount of work in requirements engineering, T5.3 implementation and coordination activities will be delayed or must be reduced.~~		~~High~~	~~High~~

1.2.1.1 Comments on the efficiency of contingency actions on foreseen risks.

- R1 Proposed contingency measures are working well
- R2 Solved
- R3 Some delays have required additional contingency measures
- R4 Proposed contingency measures are working well
- R5 Proposed contingency measures are working well
- R6 Solved
- R7 Solved
- R8 Still as defined in proposal
- R9 Solved
- R10 Still as defined in proposal
- R11 Still as defined in proposal
- R12 Still as defined in proposal
- R13 Still as defined in proposal
- R14 Still as defined in proposal
- R15 Still as defined in proposal

1.2.1.2 New risks encountered, contingency actions and comments

- R16 Solved
- R17 Solved
- R18 Gathering data delays due to busy production schedule. Additional countermeasures have been taken to speed up once the data is finally collected.
- R19 Additional delay caused by machine malfunctioning.
- R20 Additional delay due to sensorization activities
- R21 Limited access to real data. Mitigation actions proved effective. Expected to have it solved by October 2022.
- R22 Additional delay due to requirements engineering rework
- R23 New risk identified without consequences by now.
- R24 Solved
- R25 Solved
- R26 Solved
- R27 Redefine values of human dependent KPs
- R28 Solved.
- R29 Profile and monitor some partners contribution in be-weekly meetings (WP5, WP6, WP7)
- R30 Task 5.2 status is unclear. Specific meeting to work on this difficulty have been scheduled.
- R31 WP5, WP6 and WP7 tasks need to be coordinated. Regular meetings have been scheduled.
- R32 Integration of relational machine learning models does not lead to the desired improvements.
- R33 No significant improvements in ML model performance after fusing the models with KG information.
- **R34** Gender issues- researchers´ level. As recommended by the PO and experts on the M9 technical review.
- **R35** Gender issues- users´ level. As recommended by the PO and experts on the M9 technical review

1.3 Explanation of the work carried out per WP

1.3.1 Work Package 1

WP number	1	Months	1-9
WP title	Requirements and Prerequisites		
Lead partner	PRO		
Contributing partners	All partners		

1.3.1.1 Objectives

To identify and specify factors enabling successful human-AI collaboration, and to derive practical implications for human actors in all phases of AI system lifecycle, decision support systems and agile production are investigated in the context of the manufacturing domains of the use cases (injecting molding and high precision machining of large-size parts).

1.3.1.2 Activities

The activities in WP1 have been developed between M1 (January 2021) and M9 (September 2021). In this WP1, the work is finished, and detailed outcomes are available in deliverables D1.1 to D1.5, all of which have already been submitted.

Task 1.1 As-is Analysis: Completed

The current as-is situation at the use case partners, as well as problem definitions and possible integration of the Teaming.AI concept have been investigated. Use Cases 1 and 2 come from automotive suppliers and cover the process of plastic injection moulding. In detail, UC1 focuses on fault analysis of defects and the derivation of injection parameters, while UC2 deals with injection parameter optimization itself and includes automated process monitoring. UC3 investigates high-precision manufacturing of large parts. Here, the interplay between AI-controlled machine tasks and manual human labour is in focus of optimization. The contrast of UC3 compared to the other use cases highlights the universality of the Teaming.AI approach. Furthermore, the Deliverable D1.1 describes findings on the initially proposed KPIs Overall Equipment Efficiency (OEE) and Overall Labour Effectiveness (OLE). It turned out that the OEE is a generally used KPI in industry. However, the OLE is treated as non-practical KPI and even cannot be given in all use cases. For the detailed analysis report, see D1.1.

Task 1.2 Enabling Factors: Completed

A catalogue of technical and organizational conditions, influencing factors and key performance indicators for successful human-AI teaming was elaborated, considering psychological, social and technology experience criteria, and specification of how recording and evaluation should be carried out in the upcoming validation. A detailed analysis of the current state of the art was conducted and a set of key performance indicators (KPI) for every use case that are suitable to measure teaming success are provided. Results are summarized in D1.2 and include an overview of the use case problem definitions, key actors, human and machines contributors as well as key goals matching the requirements for the key performance indicators OLE and OEE. We developed a KPI selection that can represent performance influencing factors to be mapped for each use case, also matching the elements of the 4S framework for state (preconditions), structure (task mapping swim lane), skills (competence, capacities), strategies (goals). Finally, we operationalized observable-measurable variables or proxy for each necessary factor in each use case and and customized the KPI and performance influencing factors identified to each use case and the specificity of their problem definitions.

Task 1.3 Modelling of policies: Completed

In Task 1.3, we carried out a conceptual analysis of relevant human-centric AI ethical and legal issues, including those relating to autonomy, transparency, privacy, liability and so forth, so as to formulate guidance for the further project implementation. The goal was not merely to list relevant requirements on the basis of existing laws and policies, but also to identify how the requirements can be formalised and represented by means of concepts from business process modelling and knowledge graphs, so that compliance can be automatically and continuously evaluated, and to ensure that there is perfect transparency at all times for users of Teaming.AI solutions on which checks have been applied precisely, and where any potential risks may lie. As a part of this task, legal and ethics requirements stemming from the most relevant legal frameworks have been identified (including but not limited to the GDPR, the Cybersecurity Act and the proposed AI Regulation) along with a way to model these and to make them auditable in specific use cases. Results are summarised in D1.3 and include:

Specific ethics requirements, derived through the application of the principle of Responsible Innovation, on the basis mainly of the European Charter of Fundamental Rights, the EU guidelines on ethics in artificial intelligence; and the Ethics guidelines for trustworthy AI; Specific legal requirements, derived principally from the General Data Protection Regulation and from the recent Proposal for a Regulation laying down harmonised rules on artificial intelligence, complemented by general product safety regulation; A general methodology for mapping the resulting ethics and legal requirements into verifiable policies, based on standardised XML formats and knowledge graphs.

Task 1.4 Data Requirements: Completed

The task analyzed the data available from use case providers and how this data can be used to fuel the core data-driven tasks in WP2-WP4. The following steps have been carried out:

- a general overview of the data landscape of all three use cases,
- detailed analysis of data types that are made available by the use case providers,
- provide samples from datasets from each use case and comment on the potential use of these data on the development of the data-driven algorithms and the Teaming engine.

Results are detailed in D1.4.

Task 1.5 Envisioning of Teaming Engine: Completed

Based on a thorough analysis of the use cases, the Teaming.AI platform is envisioned. Concepts are taken from psychology and social science and are analysed in the context of knowledge modelling (KGs) and how to digitalize teamwork. The following key aspects have been identified:

- **Communication** level: team interactions among team members as well as between human and AI (Use Case 1 Farplas)
- **Cognition** level: knowledge transfer from human to AI (Use Case 2 Industrias Alegre)
- **Workflow** level: team and task scheduling and synchronization (Use Case 3 Goimek)

Furthermore, a concept of teaming intelligence for human-AI collaboration (by means of an operationalization of the 4S framework based on the interdependence analysis of teamwork) has been developed, the software platform and its key components have been envisioned and a proof of concept based on human and AI interdependencies has been described. Results are detailed in D1.5.

The deliverable D1.5 was extended after M9 with the results of the requirement engineering (see Appendix).

1.3.1.3 Next steps

This WP is finished.

1.3.1.4 WP risks

WP1 should originally have finished with M6, but now has been moved to M9, so there are no further plans for the next periods. The main difficulty was the current COVID-19 situation and not being able to meet the use case partner on site and visit their shop floors. This circumstance complicated the initial use case analysis. This circumstance was addressed by holding several virtual meetings with each of the use case partners in order to gain insights into the current situation. Shift of deadlines for deliverables have been necessary, to ensure quality of outcomes. In particular, Deliverables D1.1 Analysis report on human-AI teaming variants and D1.2 Catalogue of key performance indicators were moved from M5 to M6. However, the project is now on track again.
For the moment, problems raised have been solved, and no critical problems are open at present. The functional requirements have been documented and proofed but are subject to change since some key aspects of the scientific modeling of Teaming are still under research by scientific partners. To ensure further tight development of the use cases, we assigned a research partner for each use case, as shown in Table 4 below.

Table 4. Use cases with their responsible research partner.

UC	Use Case Provider	Responsible Research Partner
1	FAR	ITU
2	IAL	SCCH
3	GOI	PRO

1.3.1.5 WP1 partners' role

PRO has successfully coordinated WP1 and has lead task T1.1, produced D1.1 and has reviewed all deliverables from WP1. ITU has lead Task 1.4 Data Requirements in WP1, working closely with UC providers to design data requirement for the projects. Lead the writing of D1.4 Data Requirements report. TU Dublin has led Task 1.2 and corresponding deliverable D1.2 Enabling Factors. TIM has led Task 1.3 and corresponding deliverable D1.3 Modelling of policies. SCCH has contributed to Requirements and Prerequisites, T1.1 - T1.5; has led Task 1.5 and the requirements engineering and corresponding deliverable D1.5 Envisioning Report.
All partners:

- Deliverable D1.1: Analysis report on human-AI teaming variants
- Deliverable D1.2: Contribution and review of KPIs based on 4S framework
- Deliverable D1.3: Conceptual draft on how to integrate ethical/legal requirements in Teamin.AI platform
- Deliverable D1.4: Contribution and review of data requirements
- Deliverable D1.5: Conceptual draft on how to model teaming based on the 4S framework. Requirement Engineering report (Appendix).

1.3.2 Work Package 2

WP number	2	Months	1-24
WP title	Knowledge Graph		
Lead partner	WU		
Contributing partners	SCCH, IDEA, UMA, IDK, TYRAI, IAL, ITU, FAR, TIM, GOI, WU, PRO		

1.3.2.1 Objectives

To develop the methodological building blocks for design, population, curation and updating of the knowledge graph for human AI teaming (see building blocks 2,3 of the methodology) to address objectives B and C for developing the methodology and tools to optimize cross-functional teamwork.

1.3.2.2 Activities

These activities have been carried out from M1 (January 2021) to M18 (June 2022) so far and are still in progress. WP2 works are still going on and are slightly delayed due to delays in data provisioning from Use Cases. Detailed results will be available in this WP's deliverables, which are progressing adequately.

A key focus in WP2 in last six months was on knowledge graph population and curation (T2.2); based on an initial conceptualization of the knowledge graph elaborated in T2.1, a key focus is on concepts for constructing and exploiting domain-specific knowledge graphs through data mapping and transformation, collaborative construction and integration.

Task 2.1 KG Design: Completed

In the initial stages of the KG design process, we concentrated on the role of the KG in the overall design and architecture of Teaming.AI. This process was informed by several meetings with use case partners in order to understand the context for a Teaming.AI-based solution and find suitable architectural abstractions. This also involved an initial evaluation of the use case data available for schema design.

Another major focus was on the representation of dynamic and evolving knowledge, particularly in the context of processes, which we conceive as aggregations of traces that can be captured in a process data graph, see Figure 2. Furthermore, early work on KG foundations focused on the potential of embeddings, for instance to make predictions in graph-structured process data and to address data quality issues in event logs.

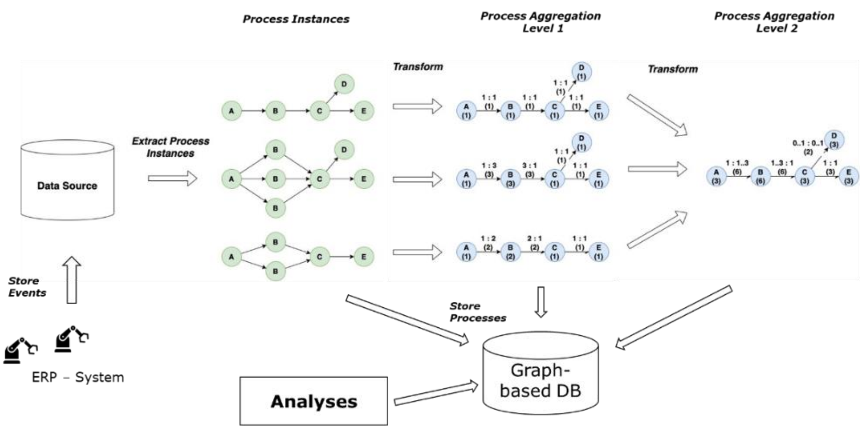

Figure 2. Knowledge Graph Design - Processes.

Results are detailed in D2.1.

Task 2.2 KG Population, Curation: In progress

To start the development and the selection of suitable KG population and curation techniques, we gathered information on the use case problems and the involved actors, i.e., human actors and AI-based actors. This served as input for the identification of a common meta-model that can be used across use cases. Several discussions to define key KG-based tasks and their integration into the overall Teaming Engine architecture led to initial steps towards the design of modular knowledge graph structures and for the organization into linked sub-graphs (e.g., production raw data, application model, meta-model, policies, process models, process data etc.). Finally, we reviewed knowledge graph embedding methods (e.g. translational distance models and semantic matching models) and their potential use for population and curation tasks.

As there is some delay in the data collection, main common actions have been taken to overcome these difficulties:

- Initial analyses of available sample data from all use cases
- Transformation of available data (FMEA, adjustment protocols) for UC2 and construction of initial prototype KG for UC 2
- UC 2 Site visit and on-site workshop on KG aspects in Valencia

Results are detailed in D2.2, to be submitted on M21. Draft advanced on M20 (August 2022).

Task 2.3 Extension of KG by manufacturing context: In progress

Initial work on identification of a common meta-model that can be used across use cases has started, as well as initial high-level KG schema for the manufacturing domain. Further progress depends on KG modeling result of Task 2.2 and therefore final results are expected to be delayed by 3 months (M23).

Task 2.4 KG Updating: In progress

Design of a resource-efficient way for dynamic KG embedding updates, that adapts based on the complexity of the KG for learning KG embeddings (PonderNet E-R-GCN). Further research on the adaptation of Evidential PonderNet on entity classification will be conducted. Progress is going on as planned.

1.3.2.3 Next steps

T2.2: Research on Knowledge graph population and curation methods, towards Deliverable D2.2 KG population due in M21.

- Continue use case modelling
- Explore mapping and population methods for use case data
- Survey collaborative knowledge graph construction approaches
- Finalize and submit D2.2 Knowledge Graph Population and Curation

T2.3: Review of existing domain ontologies and conclusion of the task.
T2.4: Extending the developed method to different use cases and applying Evidential R-GCN in an active learning setting.

- Integration, evaluation and publication of a novel update agent that combines knowledge (KG) and interpretation (embeddings) updates in a dynamic context.
- Development of Learning tasks on the KG – explore interfaces to WP4

1.3.2.4 WP risks

Main risk currently is the limited access to real-world data from the use cases due to COVID related reasons and delays in sensor deployment due to supply line disruptions. Currently, sensor installations are finished and UC partners are in process of collecting data. Dataset snapshots are available and can be used for method development. Where possible, synthetic datasets have been used. We expect major delay in deliverables but no danger for the achievement of the objectives of the project.

1.3.2.5 WP2 partners' role

WU is leading and coordinating WP2, tasks T2.1 KG Design and T2.2 KG Population, Curation, and corresponding deliverables D2.1 and D2.2. SCCH is leading task T2.3 Extension of KG by manufacturing context, and corresponding deliverable D2.3. UMA is leading task T2.4 KG Updating, and corresponding deliverable D2.4. FAR has been working on Task 2.3 collecting and providing industrial knowledge on plastic injection about plastic manufacturing errors and their potential solutions and related parameter adjustments. TYRAI has worked on the support in the design of the Teaming model; support over mapping techniques and links prediction and completion techniques that fill missing facts within knowledge graph over UC2 implementation; support in key performance indicators (manageable update cycle, computational complexity analysis or scalability) over UC2 implementation and integration. Other partners: Work closely with the other scientific partners and provided feedback on the structure and methodology on knowledge graphs.

1.3.3 Work Package 3

WP number	3	Months	2-24
WP title	Teaming Model		
Lead partner	WU		
Contributing partners	SCCH, UMA, IDK, TYRAI, IAL, ITU, FAR, WU, TU Dublin, PRO		

1.3.3.1 Objectives

To develop the methods for modelling and controlling static and dynamic aspects of teaming as outlined in Building Block 1 and 4 of the Teaming.AI methodology by adopting methods from business process modelling and trust models in order to tackle Auditable Ethics (A), Agile Development (B) and Operational Performance (C).

1.3.3.2 Activities

These activities have been carried out between M2 (February 2021) and M18 (June 2022) so far. WP3 works are going on as scheduled. Task 3.1 is detailed in Deliverable D3.1, which has been submitted in M9. Other tasks progress will be detailed in upcoming deliverables, which are progressing adequately, and they are expected to be submitted on time.

Task 3.1 Design of Teaming Model: Completed

This task investigated modelling formalisms and options for the design of a teaming model that structures the interactions between participants in human-AI teaming scenarios, which will become a key capability of the Teaming.AI platform. Starting from high-level project objectives, we developed a teaming model that can be used to orchestrate processes across human actors and AI agents and facilitate their cooperation towards a common goal. We derived a set of requirements, evaluated design options, and developed a model to represent the key concepts necessary for the orchestration of teaming processes. The teaming model will be enacted by a teaming engine, a core component in the Teaming.AI platform developed in the project. Based on the use case descriptions, we analyzed how the teaming model will be used by and interact with other components in the overall architecture to provide a flexible and agile framework for the development of dynamic teaming processes. As a demonstration, a first proof-of-concept of a teaming engine has been implemented, which reads a teaming process model (modelled in BPMN) and is able to communicate Teaming Events to execute activities.

Task 3.2 Patterns and Meta Models: Completed

First interdependence analysis of all three use cases will be further detailed based on interviews with factory workers and knowledge engineers on site. The first draft of policies for performer/supporter role assignment have been developed. Deliverable 3.2 consisting of a technical report was submitted, including an extended meta-model for the Teaming Process Model that formalizes domain-specific concepts related to teaming as well as first instantiations of the meta-model for all three of the Teaming.AI use cases, accompanied by the Activity, Policy and Event models.

Task 3.3 Teaming Dynamics. In progress

We started to analyze methods that allow for the integration of situation awareness into the KG and can be used to control the dynamical aspects in the teaming model (Task 3.1) like changes of the team/role configuration. The developed method is based on dynamizing existing Knowledge Graph embeddings and can be also used for archiving knowledge graphs. It is planned to make the code available to the public by issuing the NaviPy python package on github. NaviPy was presented on the ESWC'22 and a paper on the standardization of time-awareness in knowledge graphs has been submitted to SEMANTiCS'22 conference.

1.3.3.3 Next steps

- Alignment of the teaming model with Task 5.1 (Software Architecture). Publicly available benchmark datasets are used for testing the methods. Testing on the data of the partners will start soon.
- The first draft of policies for performer/supporter role assignment will be discussed with use case providers.
- Release of the finalized NaviPy Framework including an associated paper
- Implementation of NaviPy within the Teaming Engine
- Extending NaviPy to allow for explanations of graph-based predictions
- Integration of conventional and relational machine learning methods

1.3.3.4 WP risks

Risks have been monitored and analyzed from M1 to M18; progress is running without danger for the achievement of the objectives of the project.

The main problem with the WP is the lack of real-world data from UC providers. Mostly due to COVID related reasons, installation of the sensing hardware was delayed and couldn't obtain any data for UC2 and UC3. Data for UC1 is mostly in the computer vision related tasks available. Since development of ML algorithms are strongly dependent on these datasets, the progress in the Task 3.3 was negatively affected. Action taken to mitigate this difficulty has been the use of publicly available datasets as benchmarks for evaluating the developed methods. A further risk is that the integration of relational machine learning models does not lead to the desired improvements in performance. However, relational ML could be still useful for the generation of possible explanations of graph-based predictions. That direction still has to be elaborated.

1.3.3.5 WP3 partners' role

UMA is leading and coordinating WP3, Task T3.3 Teaming Dynamics, and corresponding deliverable D3.3. WU is leading task T3.1 Design of Teaming Model, and corresponding deliverable D3.1. SCCH is leading task T3.2 Patterns and Meta Models, and corresponding deliverable D3.2. Other partners: Work closely with the other scientific partners and provided feedback on the structure and methodology of the teaming model.

1.3.4 Work Package 4

WP number	4	Months	2-27
WP title	Machine Learning		
Lead partner	ITU		
Contributing partners	SCCH, IDEA, UMA, TYRAI, IAL, ITU, FAR, WU		

1.3.4.1 Objectives

To develop the machine learning methods not covered in WP2 or WP3 for Agile AI system development (Objective B) and Cross-functional teamwork: (i) adoption of advanced ML techniques for knowledge extraction; (ii), novel approaches in relational machine learning as basis for KG updating and recommendation systems based thereupon and (iii) adoption of ML techniques as underlying ML methods to implement the use case, as e.g. transfer learning as emerging technology in Use Case 1.

1.3.4.2 Activities

These activities have been carried out between M2 (February 2021) and M18 (June 2022) and are still in progress. WP4 works are slightly delayed due to data collecting delays in WP7. Detailed results will be available in the deliverables, which are progressing adequately, and are expected to be submitted on time (D4.2, D4.3). Deliverable D4.1 has been delayed by 3 month to M21.

Task 4.1 ML for Knowledge Extraction: In progress

Three main activities are being carried out in this task: First, the development of deep learning-based computer vision algorithms for **visual fault detection** (to be used in UC1), cf. Figure 3. The objective of this task is developing an algorithm that can identify faults (such as cracks, flashes etc.) on the produced part by processing an RGB camera image. The algorithm's performance has already been validated across >1000 real plastics parts with >90% accuracy in detection of faults. The integration of the algorithm to real-time manufacturing environment has started. This task was mostly developed during M6-M12, but significant progress was achieved during the current period.

Second, the development of machine learning algorithms for predicting **faults from injection machine parameters** (to be used in UC 1 and 2). The objective of this task is developing an algorithm that can predict whether a faulty part is going to be produced or not, based on the current process parameters/settings of the injection machine. The secondary objective is to predict how the parameters should be adjusted so that risk of faulty part production is minimized. Several different machine learning algorithms were benchmarked from data collected from UC1, where a prediction accuracy of >90% was achieved. The development of novel deep learning models for improved accuracy has started.

Third, Pose Ergonomics Assessment and Human Intervention Prediction for Heavy Machinery Operations (UC3): The aim of this task is to develop a machine learning model that can process camera images obtained from the workshop floor, detect human operators and their respective poses within the field of vision, and then predict an ergonomics metric to measure/assess the safety of their current pose. Majority of this concept/sub-task was developed within the current reporting period.

Task 4.2 Relational ML: Starting

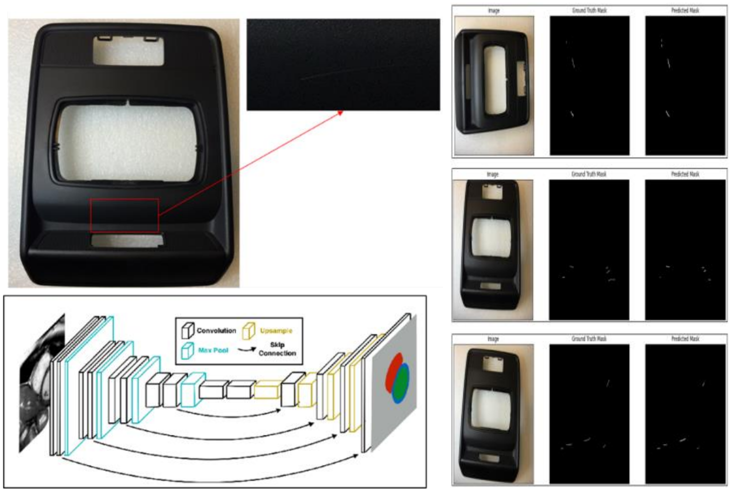

Figure 3. Automated Visual Quality Inspection.

This task aims to develop relational learning methods to push the performance of the ML algorithms developed in T4.1 and elsewhere. The algorithms are not specifically developed for UCs as in T4.1, but rather focuses on concepts that can be applied to all UCs. Sub-tasks with significant progress are presented below:

- Extracting KGs from UC domain knowledge from test processing on guideline documents: This task involves processing text-based data from use cases (and related documents) to extract relational structures and exploit this data to build KGs that can be used for various purposes. The initial concept of this task was developed during M6-M12, but a more concrete approach and progress were obtained within the current period.
- Fusion of KGs obtained from UC domain knowledge with traditional ML models for better prediction performance and efficiency: The objective of this task is to develop methods that can fuse the prediction from traditional ML methods developed in T4.1 with KGs obtained from UC documents to improve prediction metrics, such as accuracy and/or efficient metrics such as sample complexity.

- Fusion of KGs obtained from UC domain knowledge with traditional ML models for better explainability: The objective of this task is to develop methods that can fuse the prediction from traditional ML methods developed in T4.1 with KGs obtained from UC documents to improve explainability of predictions/decisions made by the ML algorithms, so that outputs of ML algorithms are easier to debug and process by human operators.
- Fusion of KGs obtained from UC domain knowledge with traditional ML models for more tractable process change recommendation: The objective of this task is to develop methods that can fuse the prediction from traditional ML methods developed in T4.1 with KGs obtained from UC documents to improve the optimization of process parameter changes, so that overall parameter recommendation computation time and recommendation quality is enhanced by KG fusion.

Task 4.3 Transfer learning: Just started.

This task aims to utilize and adopt techniques from domain adaption and transfer learning as emerging ML technique for reusing data and pre-trained models, to increase the efficiency for training

- the knowledge extraction models from Task 4.1;
- the knowledge discovery models from Task 4.2;
- the quality inspection models for Use Case Scenario 2;

It will be developed a novel transfer learning methodologies to address issues in manufacturing domain, together with a novel deep learning architectures for transferring solutions across different product quality assessment problems. First meetings have been planned and being carried out. However due to delays in data collection, the start of the main work in this task will be delayed. Currently we don't expect that delays will affect other tasks and the final deliverable is expected on time.

1.3.4.3 Next steps

- Complete all basic ML algorithms across all UCs and validate their performance on large-scale data and submit Deliverable 4.1 (delayed to M21). Expand the fault detection training data set, add connection to visual detection, and investigate inverse operation (from fault to parameters).
- Support further development of knowledge graphs and Teaming model with data from the perspective of use cases, in more depth. Specifically, exploration of algorithmic ideas (related to fusion of ML and KGs for better efficiency, explainability and tractable optimization) and submit papers and submit Deliverable 4.2 (delayed to M22)
- Enhance ML models developed for UC 1, UC2 and UC3 based on new data sent by UC providers and start developing transfer learning models between UC1 and UC2.
- Obtaining results on KG-ML Fusion Models.

1.3.4.4 WP risks

Risks have been monitored and analyzed from M1 to M18; progress is running without danger for the achievement of the objectives of the project.

Currently, the most important risk is data collection. We need access to large amount of data from all UCs. We are resolving with some meetings with the WP leaders. The lack of large amounts of data across all UCs is still a problem, but significant progress was made compared to previous period. Currently all UCs have some form of representational data that is sufficient for building model

architectures and developing concepts form technical methods. Since sensor installation and data collection infrastructures are also mostly complete, it is expected that data collections issues will be completely solved during the next period. Since deliverable 4.1 and 4.2 are also effectively postponed, we do not expect any future major issues in the WP.
Another potential risk is not seeing any significant improvements in ML model performance after fusing the models with KG information. We need to re-assess how KGs are going to be useful in the context of ML models in UCs.

1.3.4.5 WP4 partners' role

ITU is leading and coordinating WP4, Task T4.1 ML for Knowledge Extraction, and corresponding deliverable D4.1. UMA is leading task T4.2 Relational ML, and corresponding deliverable D4.2. SCCH will lead task T4.3 Transfer learning, and corresponding deliverable D4.3. FAR has been working on Task 4.1 working on industrial notes related to injection moulding process have been collected from employees and managers and combined with stored data; and the handwritten industrial notes on plastic injection were shared with partners to extract written knowledge. TYRAI has been contributing to the follow Up meetings of ML and UCs Data Integration and Tech Requirements; coordination and providers of Data Preparation Component for ML pipeline from UC2; working on Data integration pipeline for data gathering on IAL use case (UC2); support and search ML models for the Teaming.AI development. Other partners: Work closely with the other scientific and industrial partners.

1.3.5 Work Package 5

WP number	5	Months	4-36
WP title	Teaming.AI Engine (Software Platform)		
Lead partner	SCCH		
Contributing partners	SCCH, IDEA, UMA, IDK, TYRAI, IAL, ITU, FAR, WU, TU Dublin, PRO		

1.3.5.1 Objectives

To design the software architecture for integrating the components from WP2, WP3 and WP4 in a dedicated Teaming.AI software platform and its implementation as central integration hub that is flexible, modular, extensible, scalable w.r.t to interfaces (provided by the technology integration and the use case requirements) and interoperable with commonly used platforms (e.g., Kubeflow) and standards (e.g., ONNX). For a Wide Scope of applicability (Objective D).

1.3.5.2 Activities

These activities have been carried out between M1 (January 2021) to M18 (June 2022) so far and are still in progress. WP5 works are going on as scheduled. Detailed results will be available in the deliverables, which are progressing adequately, and they are expected to be submitted on time.

Task 5.1 Architecture of Teaming engine as Generic Software Platform: Completed

Recently, all task leaders agreed on a preliminary meta-model for the software architecture (T5.1), shown in Figure 4, that serves as a blueprint for a technical proof of concept (PoC). This meta-model intends to be instantiated separately for each of the three use cases.

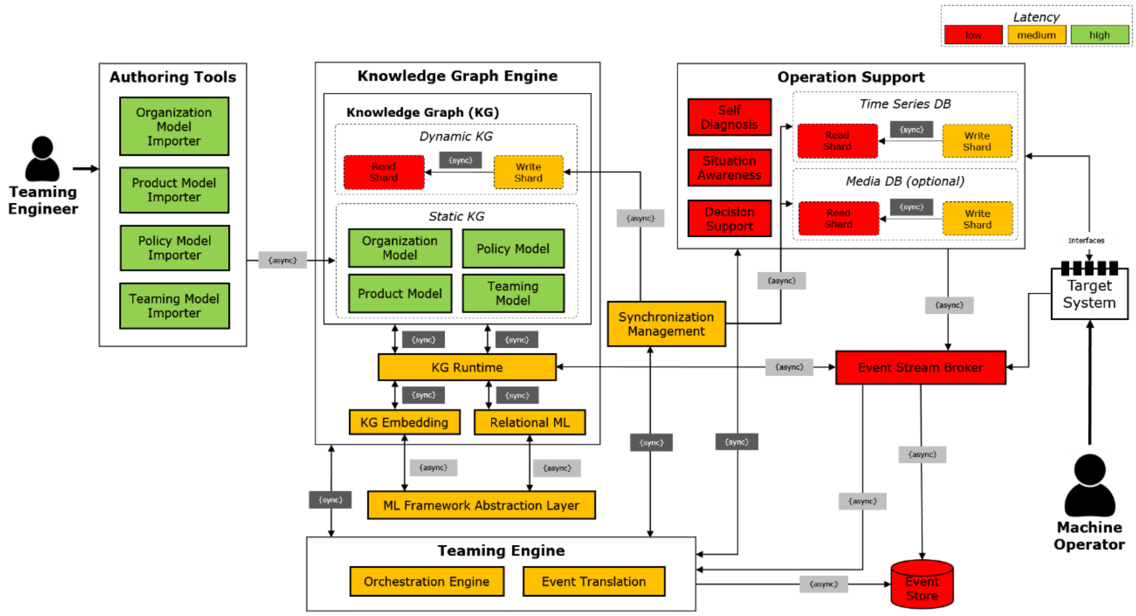

Figure 4. Architecture Development.

The software architecture for the Teaming.AI platform has been finalized based on the ISO/IEC 42010 specification (according to reviewer recommendation) and is described in detail in deliverable D5.1 (submitted at M14). ICSE publication about the software architecture presented at the International Conference for Software Engineering in Pittsburgh, USA.

Task 5.2 Authoring Tool: In progress

Key element of the authoring tool is a web-based BPMN editor with token flow simulation that has been implemented during this reporting period. In order to go further with the tool, functional and quality requirements based on ISO 25010:2011 as well as key success factors and metrics for evaluation have been elicited in several workshops with use case providers. Paper covering results from requirements engineering has been accepted at QUATIC'22.

Task 5.3 Teaming Engine: In progress

Large progress related to the development of the teaming engine (T5.3) has been made from a conceptual as well as technical perspective. The conceptual perspective focuses on the interaction sequence of the teaming process between AI and the machine operator, as well as formalisms to explicate this interaction sequence. The technical perspective, on the other hand, focuses on a scalable software architecture that can process the anticipated frequency and volume of data in the production process and allows for training the machine learning models. The interplay of the teaming engine based on the envisioned software architecture, particularly the fulfilment of required performance characteristics, is the first research focus of this proof of concept.

Work in this task included a first draft of skeleton implementation and technology evaluation for microservice discovery and provisioning.

Task 5.4 Open Source Project: In progress

Work in this task started recently and includes setup of Gitlab repository for all partners, provisioning of open-source license templates, and evaluation of interoperability of ML models and ONNX respectively. Currently defining scope of the framework abstraction layer (together with WP 6).

Task 5.5 Test and Validation: In progress

Further development of the PoC for the subsequent evaluation of the prediction quality of machine learning models. Supported by T1.2 activities, we will continuously integrate the results from this task in the software architecture during the implementation of the PoC. Integration of the ML components from Task T4.1 for continuous performance evaluation.

1.3.5.3 Next steps

T5.2: Specification of UI Elements and interaction protocols for all Use Cases.
T5.3: Implementation of prototype components of the software architecture to illustrate the interactions of the components for the different partners; technical coordination of implementation activities across the partners
T5.4: Definition of first beta version of Framework abstraction layer, together with partner UMA
T5.5: Proceeding with integration of the ML components from Task T4.1

1.3.5.4 WP risks

Due to COVID-19 travel restrictions, it was not possible to conduct the on-site interviews with the machine operators of the use case partners. This led to delays in the investigation of available data in more detail as well as the definition of the software architecture (T5.1). They are being resolved with additional meetings with the WP leaders. However, we currently do not see this as a major risk as the PoC serves to continuously validate the technical feasibility of the deliverables resulting from the preceding tasks and resolve any resulting issues thereof.
Due to the required efforts to conduct the requirements engineering, resulting from the technical review meeting in September 21, it can be expected that implementation and coordination activities related to T5.2 and T5.3 will be either delayed or must be reduced e.g., in terms of scientific dissemination of the results. Also, the concrete responsibilities of the different partners related to the implementation of the Teaming.AI platform in general need to be elaborated in more detail. This does not only relate to WP5, but also its relations to down- and upstream WPs. To mitigate this risk, we setup meetings (e.g. an implementation-focused bi-weekly meeting) with implementation partners to clarify open issues.

1.3.5.5 WP5 partners' role

SCCH is leading and coordinating WP5, Tasks T5.1 Teaming.AI Engine, T5.3 Software Framework, and corresponding deliverables D5.1 and 5.3. IDEA is leading task T5.2 Authoring Tool and corresponding deliverable D5.2. IDK is leading task T5.4 Open Source Project and corresponding deliverable D5.4. ITU is leading task T5.5 Test and Validation and corresponding deliverable D5.5. FAR has been working on Task 5.3 providing know-how and its experiences to partners in terms of how TEAMING.AI solutions could be implemented on production floor. TYRAI has been working on the follow up Teaming Engine definition and coordination of the the Use Case data acquisition component development. Other partners: active participation and contributions as requested.

1.3.6 Work Package 6

WP number	6	Months	13-36
WP title	Technology Integration		
Lead partner	IDK		
Contributing partners	SCCH, IDEA, UMA, IDK, TYRAI, IAL, ITU, FAR, TIM, WU, TU Dublin, PRO		

1.3.6.1 Objectives

To develop the framework integration layer for integrating the Teaming.AI platform into manufacturing-specific application platforms for digital twins, decision support systems and agile production tools (Objective D).

1.3.6.2 Activities

Task 6.1 Design for Integration into Application Platforms; In progress

Design the integration of existing AI infrastructures and tools in the TEAMING.AI platform will occur at the Framework Integration Layer. Connections will be established by

- the concrete tool-specific adapter interface implementations defined in the Framework Abstraction Layer (WP5)
- adapter implementations that will convert tool-specific data into generic vendor-neutral data to be used in TEAMING.AI platform and vice versa

Task 6.2 Test Planning and Validation in Simplified Tasks. In progress

Currently in design-phase of the tests based on full user requirements. Setup of a Test Management Process encompassing Software Testing (according to IEEE 829 standards for Software and System Test Documentation) based on the specification of:

- anchor points for the functionalities of each of the software components in the specific technology integration context
- simulation scenarios of different complexity
- related automated acceptance tests

Task 6.3 Preliminary Recreation of Mockup Use Cases. Just started

Working on the definition phase. Develop Mockup Screens and System Sequence Diagrams (SSD). Preliminary designs where the modelling of the use cases will be represented with focus on

- Communication between different data sources
- Human in loop
- Data processing modelling
- Optimization results
- The interaction between generated alarms and factory workers

Control dashboard mockups for each use case in planning.

Task 6.4 Integration of modules and components. Not started

This task will ensure the proper communication between application platforms and the TEAMING.AI platform for use cases through the Framework Abstraction Layer developed in task 5.4. Developments of the needed services to enable use cases to integrate with the Framework Abstraction Layer.

1.3.6.3 Next steps

- Extract and modify users-stories, which cover most of the requirements that should be tested. Furthermore, synchronize with the other WP6-tasks for automated component tests.
- Identifying/Defining Mockups and UI Screens Requirements for Use Cases platform implementation.
- Analysing and specification of Teaming activities based of System Sequence Diagrams requirements.
- Exploring of data-flows over the Teaming AI platform and definition of communication protocols with use case specific components that are accessed through the Framework Abstraction Layer.
- Coordinating and participating in meetings for facilitation of further software specification and integration.

1.3.6.4 WP risks

Currently the major risk stems from an unclear WP6 scope from the proposal, that needs to be adapted to the current developments in WP5/WP7. This includes more detailed technical specifications regarding tasks, a clarification about planned AI infrastructures and tools and the Framework Integration Layer. To mitigate the risk we initiated several workshops and a biweekly WP6 meeting schedule that builds upon the full user requirements to concretize missing information. However, due to this extra coordination work we expect a delay in WP6 deliverables.

1.3.6.5 WP6 partners' role

IDK as WP leader and task leader, PRO as task leader has contributed on the prework to extend the Digitalization Prototype for UC3 from T7.1, such that it can be used in the Teaming.AI framework in future; and TYRAI as task leader are providing support in the definition of agile production testbed for Use Cases integration, and on Use Case components definition over Teaming AI Platform. Other partners: active participation and contributions as requested.

1.3.7 Work Package 7

WP number	7	Months	3-36
WP title	Proof of Concept		
Lead partner	TYRAI		
Contributing partners	All partners		

1.3.7.1 Objectives

Integration of the Teaming.AI solution in three controlled real industrial environments (in the facilities of the industrial partners) in which performance assessment metrics will be tested and analyzed, checking the correct functioning of all components and performing any necessary tuning of the system. Dedicated training sessions with the end users and operators will also be undertaken (Objective G).

1.3.7.2 Activities

These activities have been carried out between M3 (March 2021) and M18 (June 2022) and are still in progress. WP7 works are going on as scheduled. Detailed results will be available in the deliverables, which are progressing adequately, and they are expected to be submitted on time.

Task 7.1 Digitalization of use cases: In progress

UC1: All data are made available from the machine side. FARPLAS is elaborating an integration of a Rheometer to get further information from the process. Regarding digitization of human data, the human decisions (correction of predicted fault regions) can be entered on a computer.
UC2: Application of new additional sensing to measure quality: (1) Smart thermal camera, capable of processing images and collecting part specific values of temperature. (2) Belt scale for weighing parts from injection molding machines. Furthermore, a panel PC has been installed where operators will introduce detected defects that will have a direct effect on the algorithms of the Teaming.AI platform. Finally, definition of the industrial communications that connect the injection molding machines with an acquisition server (PC_TYRIS) where the data will be stored and processed.
UC3: Shopfloor of UC3 partner site digitized in CAD and imported in camera simulation software. Different viewpoints of the tracking system have been evaluated and preliminary mounting spots have been defined. Camera hardware specifications have been calculated, defined, simulated and installed. Analysis of operator workflows at GOIMEK in close cooperation with TUD.

Task 7.2 Validation test campaign and commissioning: Starting

This task comprises the steps for assuring that all components (data, software, manufacturing) of the target application system are designed, installed, tested, operated, and maintained according to the operational requirements of the use case providers, including:

- Digital system of Farplas was upgraded to allow for better collection and storage of production data.
- Data sources (especially label data) were improved in order to provide better train and test data to solutions.
- A data pipeline was created in order to help the integration of solutions.
- The system is ready for installation and testing of the beta software components of WP5
- Delay on the initialization of the task based on the UCs digitalization delays.
- D7.2 due date postponed by M24 (due to delays in other WPs).

Task 7.3 Training: Will start in M19

Task 7.4 Validation of results: Will start in M22

1.3.7.3 Next steps

Work on T7.1.
Further work for UC1:

- Post-processing of acquired data over UC1 integration. (DATA ADQUISITION COMPONENT)
- Teaming.AI platform integration over UC1.

Further work for UC2:

- Data-pipeline integration with Injection Machines (DATA ADQUISITION COMPONENT)
- Post-processing of acquired data over UC2 integration. Injection Manufacturing Scenario. (data processing)

Further work for UC3:

- Data-pipeline integration on UC3 (DATA ADQUISITION COMPONENT).
- Post-processing of acquired data over UC3 integration.
- Further process image parts that containing ergonomic risks.
- Automatice image processing pipeline to deliver high-quality data to ITU for ergonomic risk detection.

Work on T7.2.

- Installation of the beta software components of WP5 and their integration into the target application system.
- Design and installation of the digital and physical infrastructure necessary for running all components of the target application system.
- Test UCs Digitalization

1.3.7.4 WP risks

This WP experience major delays in sensor installation due to supply chain disruptions. The Tracking System for UC3 has been installed in the end of March 2022 with a delay of more than 6 months. Sensor installation in UC2 could be finished only recently and led to a delay in data collection efforts. To mitigate the risk, we worked in parallel with the data acquisition platform such that the data collection can be accelerated after full sensor installation. Where possible, we proposed to use synthetic data for initial method testing. Currently, data collection is running, and first example datasets could be distributed to partners. However, these problems lead to a delay on the initialization of the Task 7.2.

1.3.7.5 WP7 partners' role

TYRAI is leading WP7 Proof of Concept. PRO is leading T7.1 Digitalization of use cases and corresponding deliverable D7.1. together with GOI on the improvement of definition and implementation of datasets in the UC3 and UC3 requirements definition; with IAL in the first package on sensors and first data transfer in real time and TSAS and risk assessment component.
FAR has been working on Task7.1, in which the digital and physical infrastructure necessary for running all components of the target application system are designed and installed and on Task 7.2 as task leader in which a data pipeline was created to help the integration of solutions. TU Dublin has contributed to the analysis of teaming activities in all Use Cases. Other partners: Active participation and contributions as requested.

1.3.8 Work Package 8

WP number	8	Months	1-36
WP title	Dissemination and Exploitation		
Lead partner	CORE		
Contributing partners	All partners		

1.3.8.1 Objectives

The main objective is to develop appropriate strategies for IP management, dissemination, communication and exploitation of project results. Moreover, knowledge transfer among the partners and beyond is also envisaged. The specific objectives are:

Intellectual property management of the Teaming.AI developed technology and knowledge.
To maximize the exploitation of the project results to the benefit of the Teaming.AI partners and to improve the competitiveness of the EU Industry.
To disseminate the project results and communicate the project and its relevance, making all well-known to all relevant stakeholders, and maximizing the expected impacts of Teaming.AI.
Knowledge transfer from partners to end users, students and workforce training.

1.3.8.2 Activities

These activities are carried out from M1 (January 2021) to M18 (June 2022). WP8 works are going on as scheduled. Deliverables D8.1 and D8.2 describe in detail the Teaming.AI Corporate Identity and the Communication and Dissemination Master Plan (CDMP), which is already being implemented (cf. Figure 5). Other tasks progress will be detailed in this WP coming deliverables, which are progressing adequately, and they are expected to be submitted on time.

Task 8.1 Design and Implementation of Communication Strategy: In progress

CORE has created the main aesthetic elements and channels of information that are representative of project identity. Among them are:

Visual identity (logo, templates, color palette): The visual identity of the project was finalized with the creation and selection of the official Teaming.AI logo. The colors used in the logo form the basis of the project's color palette, which was also used for the creation of the project templates in Office Word (Deliverable, Agenda and MoMs), and PowerPoint that were shared with the partners.
Social media: The Teaming.AI Twitter and LinkedIn accounts were set up and are constantly updated with project news and other related posts. So far, they have attracted 153 followers on LinkedIn and 80 followers on Twitter. The social media monitoring will continue by CORE throughout the project's lifetime. A YouTube account has also been set up and will be used as a channel for presenting project's videos at a later stage.
On M12, TEAMING.AI had 965 connections on LinkedIn and 538 followers on Twitter. On M18, these numbers have been increased by 12,3% on LinkedIn (1,084 connections) and by 12,6% on Twitter (606 followers). The social media monitoring will continue by CORE throughout the project's lifetime.
Website: The Teaming.AI website was created during the first three months of the project and has attracted 1100 unique visitors so far. The website design is consistent with the chosen color palette and involves several graphics and illustrations created by CORE to efficiently depict the project's actions and objectives. More information about the website can be found in the Deliverable 8.1.

TEAMING.AI had attracted 2500 unique visitors on M18, whereas now it counts 3700 unique visitors. Many new events and news have been added on the website.

Printed material: To enhance the project's visibility, the Teaming.AI e-brochure, leaflet, banner and poster were created and uploaded on the website. They include main facts about the project and can be distributed in events (in printed form) or through the partners' websites and organizations (in virtual form). The printed material is in accordance with the project's visual identity.
General presentation: In M9, the general presentation of Teaming.AI was created by CORE and shared with the consortium, in order to be used by partners in events presentations.
The general presentation of the project has been finalised and shared with the Consortium, to be used for dissemination purposes in several events and channels of dissemination.
Press release: As part of dissemination activities, the 1st press release was published about the Teaming.AI kick-off meeting and some general information about the project. It was uploaded on the project website and further circulated through the project's social media.
Newsletters: Finally, the 1st newsletter of Teaming.AI was launched in June (M6). What is more, Teaming.AI was included in the 4th issue of ENGINE newsletter in M6 of the project.
Finally, as part of communication activities, three newsletters have already been sent out to TEAMING.AI newlsetter database. They have also been uploaded on the project website and furtherly circulated through the project's social media.

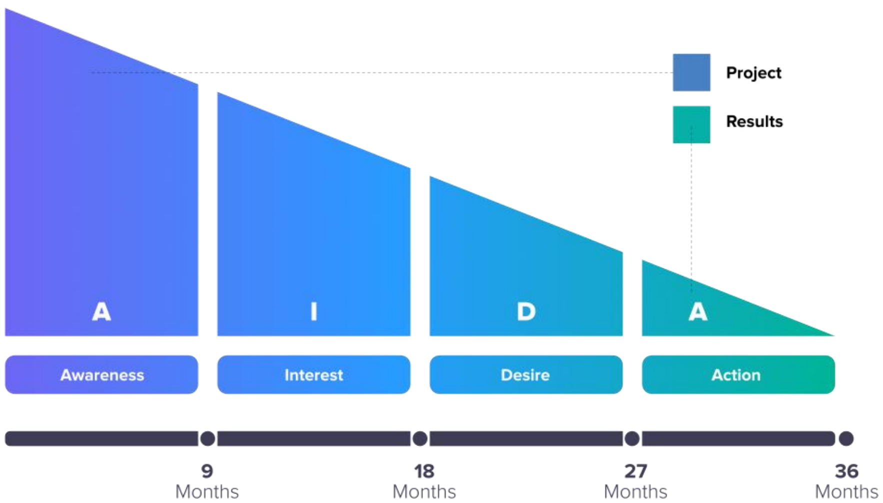

Figure 5. Overall Strategy: AIDA Model.

Task 8.2 Design and Implementation of Dissemination Strategy: In progress

Press Releases: So far, the project has published 3 Press Releases, giving information about the technical progress of TEAMING.AI up to now.
Events calendar: A calendar was created on the Teaming.AI website to be frequently updated with relevant events and conferences. This way partners can find potential events to participate in, thus enhancing Teaming.AI dissemination activities. Constant update of the events calendar (internal use) and the events calendar displayed on the website (public use).
Events and publications list: This list contains identified relevant conferences or other types of events and is constantly enriched throughout the project.

Events and publications reports: Presented to the Consortium are forms to fill in after participating in an event or publishing an article, to follow up with partners and keeping track of participations in events, focus groups and workshops. Ten publications have been published so far in the context of TEAMING.AI Project.

Zenodo & OpenAIRE accounts: TEAMING.AI has active profiles in both zenodo and OpenAIRE platform, which will boost the readers community of publications and other dissemination activities. Project's publications have been uploaded in these platforms as well.

Participation in events: Teaming.AI has been presented in the following events:

- ICT-38 workshop, aiming at clustering with projects of the same topic.
- ENGINE workshop
- DATA WEEK 2021 (cf. Figure 6)
- IoT WEEK 2021
- UAR Innovation Network 360°
- 1st ICT-48 Community Workshop | 30/06/2021
- Pakistan National AI Forum | 2/09/2021
- AK Konferenz | 10/09/2021
- 2nd ICT-38 Cluster Workshop | 12/10/2021
- PAF-IAST | 7/01/2022
- EDM Seminar Industry 4.0 and Digitalization | 3/03/2022
- AI.MAN workshop | 14/03/2022
- I-ESA Conference 2022 | 24/03/2022
- Extended Semantic Web Conference 2022 | 30/05/2022

Figure 6. DATA WEEK 2021.

Task 8.3 Exploitation strategy and IPR Management: In progress

As lead partner of Innovation Management in the project, SDP has developed the following tasks:

- Collaboration with other ICT-38-2020 projects
- Joined the ICT-38 projects mail group that coordinates all activities between the H2020 projects awarded in the ICT-38 call (Task 8.3a), see Figure 7.
- Keep track of the cluster´s pathways for collaborations between partners and with other research associations to maximize impacts.
- Participation in H2020 ICT-38 Cluster AI-MAN: 1st Workshop (Task 8.3a).
- Attendance to all use case coordination meetings to keep updated of the project progress.

- Analysis of proposal and elaboration of the first draft of Key Expected Results list (KER).
- Elaboration of a questionnaire (result identification form) that help us identify and verify with the partners the proposed KERs list.
- Sent the questionnaires to partners and began to receive feedback from them.
- Analysis and verification of the contributions received by the partners in the result identification form.
- Definition of the structure of Deliverable 8.5, in coordination with our partners from CORE innovation.
- Initial market characterization.
- These tasks have been a first step towards the completion of our two first deliverables due on M18: D8.5 Market analysis and D8.8 Preliminary Exploitation Strategies and IPR Management. Table 5 shows a proposed list of exploitable results.

Table 5. Proposed list of exploitable results.

	Exploitable Result	Nature	Lead Partner	Sector of application
1	Advanced method for building updatable Knowledge Graphs	mathematical model, software	WU	AI solutions
2	ML algorithms for knowledge extraction and updating dynamic Knowledge Graphs	mathematical model, software	UMA	AI solutions
3	Teaming.AI software platform prototype implementing Human-AI teaming capabilities, including Teaming Model	software	SCCH	AI manufacturing solutions for: quality control, equipment parameter control, machine-assisted manual operations
4	AI-based solution for automated quality inspection of plastic injection molding parts	software	ITU	Quality control processes of parts produced by injection molding
5	AI-based solution for automated process monitoring of plastic injection molding machines	software	TYRIS	Plastic injection processes, plastic injection equipment development
6	Digital manufacturing solution for Tracking and Scene Analysis	software	IDEKO	Ergonomics and risk prevention in large parts manufacturing

Figure 7. Collaboration with other ICT-38-2020 Projects.

Task 8.4 Teaming.AI Strategic management and replicability: In progress

The workplan for T8.4 was developed. Input was provided to the questionnaire for the individual exploitable results that will be sent to the Teaming.AI technology partners, cf. Figure 8.

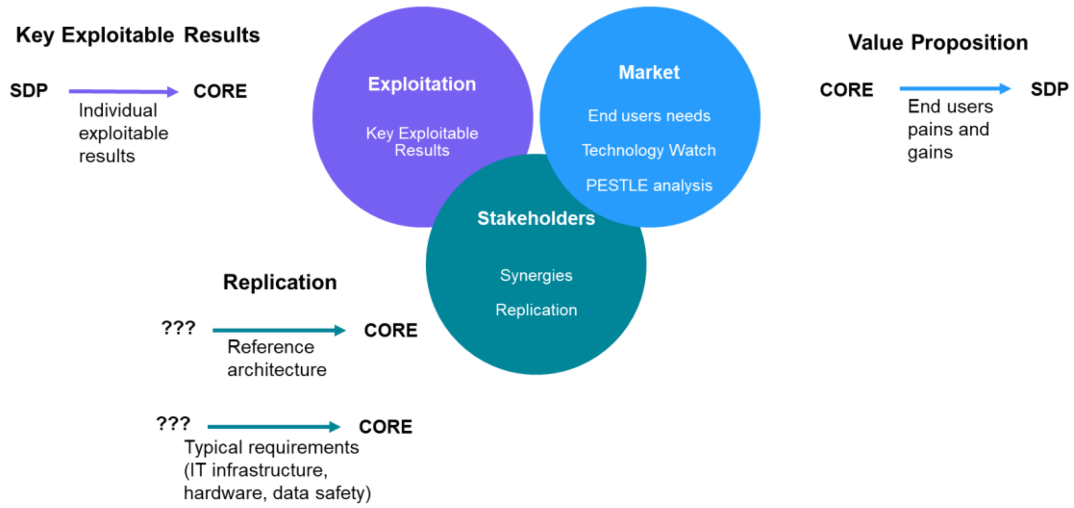

Figure 8. Exchange and collaboration with partners.

Desk Research: Thorough literature analysis to identify market barriers for AI in manufacturing. Key results include:

- Categorization of most prominent barriers into social, economic, technological, cultural, and organizational.

Online Questionnaire Survey: Based on the literature analysis and our previous work on pains in Teaming.AI, an online questionnaire was developed and circulated to our end-users that participate in the Teaming.AI consortium. Key results include:

- Creation of questions targeting operators/technicians and managers and questions aiming at each type of persona, to achieve a holistic approach.

Analysis of Market Barriers Questionnaire: Gathering and analyzing market barriers questionnaire to comprehend and demonstrate the challenges that the participants confront. The questionnaire had 6 respondents (of which 3 are operators/technicians and 3 are managers) two from each End-User. Key results include:

- Business outcomes: a) need for improvement in decision making as a primary goal and b) need of increasing productivity and agility through automation and upskilling.
- Current digitalization status: 67% of respondents indicated that their companies are still at an early phase, initiating pilots to test Industry 4.0 solutions.
- Some barriers from the literature review were not identified in our use cases, but new ones emerged as can be seen in the Deliverable 8.5.

Market Analysis: Analysis of the market through desk research to attain insights regarding the replicability of Teaming.AI and the current status of AI in manufacturing. Key results include:

- AI in the Manufacturing Industry includes analysis of a) Impact of Covid-19 on AI implementations, b) Macroeconomic view of AI, c) Current and future market size, d) Adoption of AI technologies, e) Geographical adoption of AI in manufacturing, f) Global spending on AI technologies.
- Prominent AI implementations in manufacturing processes.
- Identification of key market segments and interesting Use Cases including a) Quality Control, b) Process Control, c) Safety features, d) Design & Maintenance, and e) Augmenting human capabilities.
- Key AI solution providers in the manufacturing industry like IBM Corporation and Oracle Corporation.

Analysis of pains of End-Users through a questionnaire. Key results include:

- Machine setup parameterisation and unexpected downtimes are the biggest bottlenecks during the operators' workflow.
- Scrap is at most financially controllable but can lead to excessive waste.
- Meeting scheduling activities is a challenge.

Task 8.5 Legal and ethical requirements definition: In progress

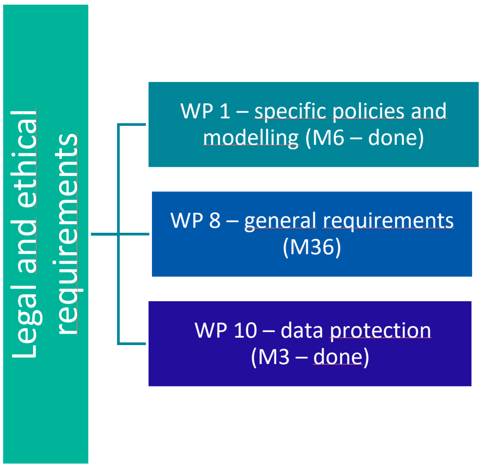

Figure 9. General structure for legal and ethics in Teaming.AI.

TIMELEX has identified critical ethical requirements derived from the GDPR, and has summarized the relevant policies and measures that will be applied in Teaming.AI (cf. Figure 9), comprising notably:

- The procedures and criteria that will be used to identify/recruit research participants.
- The informed consent procedures that will be implemented.

- Templates of the informed consent/assent forms and information sheets.
- An incidental findings policy.
- Appointment of a Data Protection Officer (DPO).
- Assurance of relevance and minimization of all of the data that will be processed.
- A description of the technical and organizational measures that will be implemented to safeguard the rights and freedoms of the data subjects/research participants.
- Explanation how the data subjects will be informed of the existence of profiling, its possible consequences and how their fundamental rights will be safeguarded.
- An initial evaluation of ethics risks related to the data processing activities of the project.

Moreover, relevant legislation and resulting requirements have been assessed, including notably the General Data Protection Regulation (GDPR), and proposed new legislation (including the Data Governance Act, Data Act, and the regulation laying down harmonized rules on artificial intelligence). These have been integrated into D1.3 Teaming.AI Policies.

Developing a standardised use case data protection compliance template; UC3 Site Visit Spain, and revision of the data protection approach; ethics assessment of UC3; and quick checks of UC1 and UC2. Participation in the Steering Committee Meetings and General Assembly; Social media contribution on auditable ethics; Research & drafting of a paper on legal compliance modelling in Knowledge Graphs; and research into legal compliance under the proposed AI Act.

1.3.8.3 Next steps

- Update website with project progress information.
- Explore the possibilities to participate in workshops and international conferences.
- Explore possibilities of clustering with other ICT-38 projects.
- Continue the analysis and verification of the contributions received by the partners in the result identification form.
- Continuous update KERs matters such as: ownership, background afforded by the partners, potential sectors of application, IP protection alternatives, etc. in cooperation with the partners.
- Continue the collaboration with the ICT-38 AI.MAN cluster on issues like marketplace access or standardization activities.
- Update PESTLE analysis by M24.
- Follow up the assessment of legal requirements, including specifically new legislative proposals (Data Governance Act, Data Act, and the AI Regulation).
- Grow digital network even further
- Publish 4th Press Release and 4th newsletter
- Explore the possibilities to participate in workshops and international conferences
- Explore possibilities of clustering with other ICT-38 projects
- Completing data protection impact assessments for the Use Cases; completing legal compliance screening and providing any necessary information notices and consent forms. Monitoring emerging legislation, principally the AI Act.
- Create project videos (short interviews on technical partners)
- Second iteration in pains & gains questionnaire to get feedback from more respondents
- Validation of Teaming-AI Value Proposition with partners
- Alignment of Teaming-AI Value Proposition with Key Exploitable Results

1.3.8.4 WP risks

Risks have been monitored and analyzed from M1 to M18; progress is running without danger for the achievement of the objectives of the project.

Tasks 8.1, 8.2: Risk concerning small network of social media accounts was avoided successfully. There are no deviations from Gantt chart of the project so far.
Task 8.3: No problems were encountered during our work and no deviation from the Gantt chart have occurred so far.
Task 8.4: No problems were identified.
Task 8.5: In April 2021, a new and relevant European legislative proposal was published, targeting AI applications in general. The proposal would introduce new potential requirements for Teaming.AI as well. The process was identified on time, and potential impacts are being assessed, concurrently with other regulatory requirements. There are no deviations from Gantt chart of the project so far.

1.3.8.5 WP8 partners' role

Contribution to D8.1, D8.2 and review of communication material (website, info material). Contribution to communication strategy (newsletter, posts). T8.2: Contribution to dissemination strategy. Contacts and dissemination plan with other ITC-38 projects has been established and lead to the launch of the ICT.38 cluster on AI for manufacturing. Dissemination of Teaming.AI on several occasions (First ICT-48 community workshop, IoT week 2021). TIM has contributed, as task leader of task 8.5, to the defining of the legal and ethical requirements for the solutions created in the project and ensures a legally compliant and ethically sound further use of developed solutions in manufacturing environments. Other partners: Active participation and contributions as requested.

1.3.9 Work Package 9

WP number	9	Months	1-36
WP title	Coordination		
Lead partner	SCCH		
Contributing partners	All partners		

1.3.9.1 Objectives

The overall objective in this WP is to create and operate the necessary governance structure for an effective project direction and management. The partial objectives are the following:

- To perform the financial, legal, administrative and technical coordination.
- To establish the communication flow and methods for reporting, progress monitoring and quality assurance.
- To coordinate activities with the EC.
- To encourage networking.
- To develop measures for avoiding risk: financial, legal, administrative and technical.
- To establish contingency plans if needed.

1.3.9.2 Activities

WP9 works are going on as scheduled. The submitted deliverables D9.1, D9.2 and D9.3 describe the general rules and methodology to ensure quality and success in achieving the project´s objectives. Further updates are expected to be submitted on time. The following activities have been carried out from M1 (January 2021) to M18 (June 2022).

Task 9.1. Global legal and contractual management: In progress

Deliverable D9.1 Governance structure, communication flow and methods was submitted successfully in M3 (March 2021). This deliverable established the project organization and management, including information about management bodies, decision making process and meetings was explained. Regarding the Project Management Organization, the list of Teaming.AI partners and the Steering Committee were included. Moreover, work package and task leaders were defined in a detailed way. In the Teaming.AI project, there is also a Scientific Advisory Board (SAB), which has only advisory role, and does not directly participate as member of the Consortium. The list of the members who make up the Scientific Advisory Board and the names of enterprises they belong to is also included. All this previous information was written with the objective of defining the role played by each partner and person that takes part in the Teaming.AI project. Finally, the conflict management and deviation management were included and described in detail.
Other activities carried out in this task were the collection of amendment requests, preparation and submission of amendments, the main one being the change of partner Tyris Software (outcoming) and Tyris AI (incoming). SCCH has led the introduction of Teaming.AI to new POs from HADEA.
A brief interview greeting new Project Officer, Mr. Javier Mata Gómez, and introducing the project took place in April 2022. Due to the implementation of M9 technical review recommendations, deliverables D3.2 Teaming Model Initialization and D5.1 Software Architecture were affected. Its submission was delayed 2 months (from M12 to M14) previous acknowledgement of present PO.
Due to the difficulties to collect actual and enough data from use cases, 6 technical deliverables, all of them linked were assumed to be delayed between 2-3 months. This was communicated to present PO. These deliverables are: D2.2 KG Population Methodology; D2.3 Industrial KG; D4.1 ML Driven Knowledge Extraction; D4.2 ML Driven KG based Recommendation Systems; D7.1 Use Case Digitalization; and D7.2 Use Case Commissioning. However, actual PO required to submit a complete and sound version of D2.2 and D4.1 (due date M18) by the end of M20 to be included in the review of the first periodic report.

Task 9.2. Financial and administrative management: In progress

Close-up financial monitoring has been carried out every six months, shared and commented with partners in M18 General Assembly Meeting. Main indicators are calculated as explained:

- Progress: According to actual progress detailed in Gantt chart.
- Total Costs (planned): as detailed in the Budget (Grant Agreement).
- Total Costs (actual): data collected from each financial report.
- Earned Value (EV): calculated as % Progress x Total Costs (planned).
- Cost Performance Index (CPI): calculated as Earned Value / Actual Costs.
- Conclude Performance Index (TCPI): calculated as (Total Costs (planned) - EV) / (Total Costs (planned) – Total Costs (actual))

The technical progress has been calculated considering the delays of WP2-WP7 being 2-3 months. It is needless to point out that the costs of M18 (June 2022) have been calculated as an estimation due to the month was not finalised. To analyse cost deviations, the earned value (EV) must be compared with the actual cost. This comparison can be done through the Cost Performance Index

(CPI). If the CPI is less than 1, it is showing inefficiency because more is spent than is worked. A CPI greater than 1 indicates efficiency in the use of resources. The TCPI index measures the relationship between what remains to be worked and the remaining funds. It indicates the cost efficiency necessary to achieve the total budget of the project. If the TCPI is less than 1, this indicates that we have a good expense per percentage of project progress.

Financial monitoring M1-M18

Global financial monitoring from M1 to M18 is presented in following table and chart.

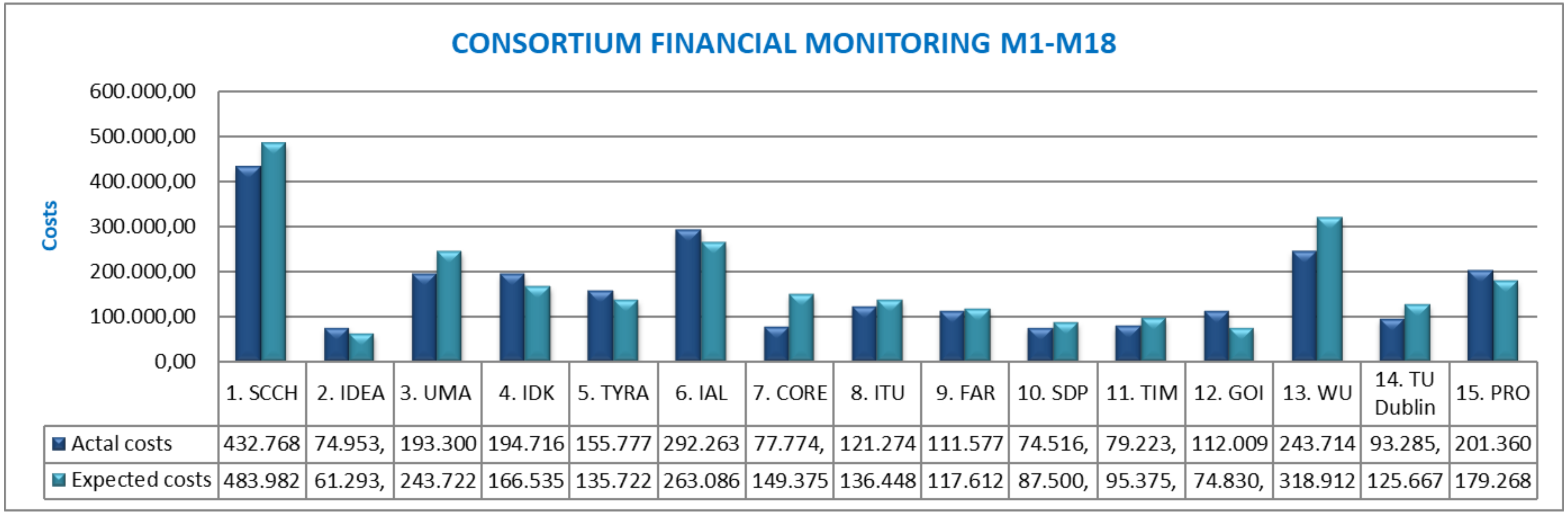

Figure 10. Financial Monitoring versus expected expenses at M18.

WPs	Period (months)	Technical Progress	Person months (planned)	Person months (actual)	Person months (Earned Value)	(A) Direct Personnel costs (planned)	(A) Direct Personnel costs (actual)	(B) Direct costs of sub-contracting (planned)	(B) Direct costs of sub-contracting (actual)	(D) Other direct costs (planned)	(D) Other direct costs (actual)	(E) Indirect costs (planned)	(E) Indirect costs (actual)	Total Costs (planned)	Total Costs (actual)	Earned Value (EV)	Cost Performance Index (CPI)	To Conclude Performance Index (TCPI)	% (total costs (actual) / total costs (planned))	% total costs (actual) / EV
WP1	M1-M6	100%	34,00	28,15	34,00	204.769,00	178.451,27	0,00	0,00	0,00	1.420,78	51.192,25	39.266,42	255.961,25	219.138,47	255.961,25	1,17	0,00	85,61%	85,61%
WP2	M1-M24	74%	68,00	45,01	50,32	390.854,00	236.176,33	0,00	0,00	0,00	995,33	97.713,50	57.968,80	488.567,50	295.140,46	361.539,95	1,22	0,66	60,41%	81,63%
WP3	M1-M24	81%	48,00	41,06	38,88	301.297,00	259.594,79	0,00	0,00	0,00	7.762,00	75.324,25	65.034,70	376.621,25	332.391,49	305.063,21	0,92	1,62	88,26%	108,96%
WP4	M2-M27	49%	56,00	33,41	27,44	277.030,00	156.433,94	0,00	0,00	17.100,00	4.467,70	73.532,50	35.866,06	367.662,50	196.767,70	180.154,63	0,92	1,10	53,52%	109,22%
WP5	M4-M36	44%	152,00	60,16	66,88	799.922,00	299.490,18	0,00	0,00	7.000,00	3.904,23	201.730,50	61.171,31	1.008.652,50	364.565,72	443.807,10	1,22	0,88	36,14%	82,15%
WP6	M13-M3	6%	89,00	14,65	5,34	470.208,00	97.052,03	0,00	0,00	201.160,00	7.131,92	120.964,50	14.875,24	792.332,50	119.059,19	47.539,95	0,00	1,11	15,03%	250,44%
WP7	M3-M36	30%	168,00	49,80	50,40	851.309,00	311.461,75	0,00	0,00	191.650,00	119.284,46	307.117,25	97.767,74	1.350.076,25	528.513,95	405.022,88	0,77	1,15	39,15%	130,49%
WP8	M1-M36	50%	95,00	42,79	47,50	467.648,00	173.021,98	0,00	0,00	87.500,00	3.753,91	137.037,00	39.805,45	692.185,00	216.581,34	346.092,50	1,60	0,73	31,29%	62,58%
WP9	M1-M36	50%	29,00	13,51	14,50	189.034,00	93.926,40	0,00	0,00	130.000,00	18.785,11	79.758,50	29.060,37	398.792,50	141.771,88	199.396,25	1,41	0,78	35,55%	71,10%
Total			739,00	328,54	335,26	3.952.071,00	1.805.608,67	0,00	0,00	634.410,00	167.505,44	1.144.370,25	440.816,09	5.730.851,25	2.413.930,20	2.544.577,71	1,05	0,96		94,87%

Table 6. WPs Financial Monitoring M1-M18.

Figure 10 and Table 6 show, for each work package, the cost planned detailed in the proposal budget and the costs actually incurred for each type of cost. The earned value is the estimation of the costs in these first 18 months if everything were as planned. The main conclusions of this financial monitoring are: In general, the executed costs are in line with the expected costs according to the percentage of technical progress. Some partners exceeded the earned value in WP3, WP4, WP6, and WP7 respectively. In conclusion, the financial progress is on target, despite the technical progress delay of some WPs.

Task 9.3. Organization of Kick-off and periodic meetings: In progress

Teaming.AI kick-off meeting took place on the 9th of February, online. Project Officer Jaakko Aarnio from CNECT attended the meeting. Every 6 months, a General Assembly was established to be held between all members of the consortium. On 8th and 9th of June 2021, the first General Assembly (M6) took place, also online. M12 General Assembly took place on 7th of February 2022, also online. Agenda, WP presentations and minutes are kept in the SCCH Teams repository. SCCH internal reviews of TEAMING.AI project progress has continued first Mondays of every month. Steering Committee´s WP status review has changed to Tuesdays (first of the month) on a monthly basis, from 13h to 15h, to put all technical issues and needs widely in common and take coordinated decisions to boost the progress of the project. Transversal WPs news and needs are also communicated. M18 General Assembly took place in SCCH-Hagenberg (Austria) on the 9th and 10th of June 2022. 1st Periodic Review has been scheduled on the 8th of September 2022 online.

Task 9.4. Monitoring of project progress: In progress

Every six months, an internal report was and will be collected to monitor WP and partner technical progress, and partner financial report. Results were and will be analyzed and commented with each partner. SCCH has established an internal review of the Teaming.AI project progress on the first Monday of every month. The Steering Committee has agreed to hold a WP status review on the first Tuesday of every month, to check the progress, needs, and possible difficulties.

SCCH is also leading the Technical Review meeting on October 21, 2021. The status of every WP is surveyed every month in the Steering Committee. A 6M brief written report by WP and partner is collected, also in M12, last one on M18. This information is the basis to start the progress report deliverable D9.4 submitted on M18.

Task 9.5 Data management and Security: In progress

Deliverable D9.2 Data Management and Security Plan was successfully submitted on M3 (March 2021). This document aims at ensuring the proper management of confidential information used within the project. It includes: collection, processing, storage, and exploitation, applicable methodologies and standards to be observed, whether and how this data is shared and/or made available for open access and how this data is curated and preserved during and after the project in compliance with national and EU legislation. The monitoring and implementation of the Data Management and Security Plan is carried out by SCCH.

Online data are stored on a secure server provided by the coordinator. Moreover, all research activities requiring public participation and data collection are carried out in accordance with the ethical principles for the protection of individuals as set out in EU Parliament Directive 95/46/EC and Directive 2002/58/EC, as modified by Directive 2009/136/EC. This task is linked to WP10 Ethics Requirements.

Data Management and Security Plan will be updated along the TEAMING.AI project development. On M18 an update is presented in section 4.

Task 9.6 Quality and Risk Management: In progress

Deliverable D9.3 Quality assurance Plan and Risk Management (D9.1) was also successfully submitted on M3 (March 2021). This methodology establishes the basis for monitoring the project deliverables' progress, ensuring that they are elaborated according to specification and foreseen planning. The list of deliverables, including the leader of each document and the due date was included. Furthermore, the official reporting and the internal reporting was explained. The Risk Management Plan plays an essential role in Teaming.AI project. This plan has been defined in order to deal with potential problematic situations related with the research and development activities or the management of the project. Anticipating possible difficulties could ease their impact to the project. Consequently, the identification and evaluation of adverse situations and a possible contingency plan to address these issues has been studied, concluding that no critical risk existed until present days.
Several key management roles (quality manager, risk manager, etc., see D9.1 for details) have been created to have an independent board to oversee PM activities. The Scientific Advisory Board (SAB) has been reviewed every 6 months as the General Assembly Meetings. This SAB has been established and for consultation the next meeting is planned for summer 2022. Each deliverable will be reviewed by the corresponding work package leader and by the coordinator, corrected or completed, if needed, before being submitted. After the reviews report the deliverable´s template has been reviewed and shared with the Consortium. Continuous assessment to solve partners´ doubts has been maintained. Some difficulties are impacting on the timeline of the project. Actions are being taken, such as dedicated on site use case 2 and 3 visits. Results of these contingency measures are expected to confirm they are really problem-solving. Updated deliverable template is annexed at the end of this deliverable.

1.3.9.3 Next steps

The project runs well, and deliverables are finished on time. Collaboration between partners works well despite the virtual meetings that allow less space for non-formal talk. However, it is expected that next General Assembly Meeting will be held at one of the use case partners, still to be determined. Tasks 9.1 to 9.6 will continue supporting and taking care of the project progress. Main activities planned are the organisation of the Technical Review Meeting in Sept., organizing Use Case specific meeting as needed, monitoring and reporting of all observed deviations and contingency measures to the PO, and organizing the 4th GAM to be held at the beginning of January.

1.3.9.4 WP risks

Risks have been monitored and analyzed from M1 to M18; progress is running without danger for the achievement of the objectives of the project.

A risk review was integrated as one additional bullet point in each monthly Steering Committee meeting in order to act to encountered problems in a timely manner. Risk assessment is done together with the risk manager (G. Stübl) and documented in a separate risk table. Currently, the data collection is a bottleneck for further progress of the project. Due to Covid and supply-chain disruptions, the installation of required sensors in UC2 and UC3 was delayed, and data acquisition could not be processed as planned. To mitigate the problem, we worked with simulated data where possible but in the end also had to adapt the timeline of dependent deliverables to reflect these problems.

Preventive actions have been proven enough to promote the project progress. In other areas, actions have been taken:

- Monthly Steering Committee meetings online.
- Use case 2 and 3 dedicated onsite visits.
- WP2, 3 and 4 monthly meetings to coordinate core development of Teaming.AI
- WP5 coordination meetings to facilitate use case demos development of Teaming.AI
- WP5, 6 and 7 monthly meetings to coordinate the implementation of Teaming.AI.

1.3.9.5 WP9 partners' role

All partners are collaborating smoothly. The current delays in data acquisition due to delays in sensor deployment will be soon resolved and the delay in upstream work packages is taken care of through a work plan adaptation. General work progress is on track and already achieved intermediate results are presented at several top scientific conferences. The project is likely to keep the timeline as initially proposed.

1.3.10 Work Package 10

WP number	10	Months	1-36
WP title	Ethics Requirements		
Lead partner	SCCH		
Contributing partners	All partners		

1.3.10.1 Objectives

The objective is to ensure compliance with the ethics requirements set out in this work package.

1.3.10.2 Activities

The current section aims at summarizing all the work involved in Teaming.AI continuous ethical screening, performed until the end of M18 (June 2022). The ethical screening under the scope of Teaming.AI focuses on following a "collaborative AI decision making, user and data-driven" methodology. Its success depends on an active involvement of users (industrial partners) during the entire lifecycle. To warrant this, two specific partners have been involved since the start of the project: TU Dublin focused on the social aspects and TIMELEX focused on all EU policies. This approach will require human participation for the implementation of the project. Every study or data collection involving humans as part of Teaming.AI complies with ethical principles and with applicable international, European and national law. The researchers ensure the respect for people and for human dignity, fair distribution of research benefits, and the protection of the values, rights and interests of research participants.

Participants are asked for their consent for monitoring and analyzing their activities, opinion and evaluations. It is not expected that the participants' psychological, social, legal economic, environmental, etc. status are put at risk at any moment.

As a result, the Deliverable D10.1 (H-Requirement No.1) is focused essentially on the latest H2020 ethical guidelines and its recommendations, so the entire consortium acts in accordance with the compulsory procedures. For this deliverable, IAL, SCCH and TIMELEX have worked together to issue a complete and properly aligned document in M3 (March 2021), which will be followed and further developed during and beyond the project.

1.3.10.3 WP risks

No additional risks identified after the Grant Agreement.

1.3.10.4 WP10 partners' role

The main roles in this WP have been (1) IAL as leader of deliverable D10.1 H-Requirement No.1; (2) SCCH as WP leader and coordinator of its implementation during the project; (3) TIMELEX as expert on these topics and who has later developed Deliverable D1.3 Teaming.AI policies (M6-June 2021), and will survey and report in WP8, Deliverable D8.10 Legal and ethical requirements report in M36 (December 2023).

The rest of partners have been informed of this deliverable and of the obligation to follow it, as established in the Grant Agreement.

1.4 Impact

Regarding Teaming.AI´s impact, the information in Section 2.1 of the DoA is still relevant and keeping its targets, so, at present, it does not need to be updated.

2 Update of the plan for exploitation and dissemination of result (if applicable)

The first Communication and Dissemination Master Plan (CDMP) (D8.2) was submitted in June 2021 (M6), and Teaming.AI Corporate Identity (D8.1) was submitted in March 2021 (M3), thus there is no current need for further update.

Based on the DoA, there are two reports of execution in M18 and M30. Thus, there is no need to update Communication and Dissemination Master Plan. When related KPI are analyzed, it will be considered if a review of the Communication and Dissemination Master Plan is required.

As recommended in M9 technical review, the following actions have been implemented:

- Action 10. Lead by CORE. A **matrix with multiple data selection** will be available and updated continuously by all partners. For each identified Exploitable Result and the Key Exploitable Results (KERs), the matrix will list the related Communication, Dissemination and Exploitation activities that will be performed during the duration of the project. Regarding the Exploitation activities, the focus will be on: (1) Identifying the key stakeholders that will exploit project results, (2) Describing the exploitation roadmaps for project results and, (3) Correlating the technical readiness level of project's result with the launch of the exploitation phase. The description of the matrix is reported on D8.3 First Report on Dissemination activities. (M18)
- Action 11. Lead by SDP. A **workshop** will be carried out with all partners ASAP, which will be the base for the recommended **matrix and the IPR** management strategy. This work and outcomes are reflected on D8.8 Preliminary Exploitation Strategies and IPR Management (M18).
- Action 12. Lead by CORE. **Customized dissemination** needs will be depicted in an overall matrix, as stated in Action 10. In the Communication plan submitted on M6 (D8.2 Communication and Dissemination Master Plan), we have included a table presenting all the target audiences, as well as a table of the indicative events in which we plan to participate during the project. More specific links between the events and the target audiences will be presented in D8.3 (First Report on Dissemination activities - M18, in D8.4 (Second Report on Dissemination activities - M30) and on Final progress report - M36. These links will be reflected through tables that mention the events in which the Consortium participated, along with the audience targeted.
- Action 13. Lead by CORE. Add **checking point on acknowledgment** in Quality control to be reflected on D8.3 First Report on Dissemination activities (M18); D8.4 Second Report on Dissemination activities (M30) and Final progress report, WP8´s results M36.
- Action 17. Lead by CORE. Now that the project has started producing its first results, we will incorporate updates on the **homepage** of TEAMING.AI. We still want to keep all the general information of the project there, but we will **add some carousels** and other features, which will show some more up-to-date information on the project.
- Action 18. Lead by CORE. We have already created a **subpage on the website**, which will host all **public and accepted deliverables**. They will all be available for downloading (https://www.teamingai-project.eu/project-deliverables). Up to now, 6 public and accepted deliverables have been uploaded on the website.

- Action 21. Lead by CORE. We will emphasize on **projecting events and news on the website** and give a more dynamic appeal to the website.
- Action 22. Lead by CORE. We have already a **dedicated page named "Resources", on the website** in which all news and communication materials can be found. As the project evolves, these sections will be furtherly updated and enriched.

The results of this updating are detailed in D8.3 First Report on Dissemination activities and D8.8 Preliminary Exploitation Strategies and IPR Management (M18) will be submitted in June 2022, together with the deliverable D8.5 Market analysis (M18).

3 Follow-up of recommendations and comments from previous review(s) (if applicable)

The present review is the first periodic review of this project. However, in M9 a technical review took place. An action plan was derived from recommendations received. The answer to this recommendation was submitted on the 4th of December of 2021.

The status of each action is presented in Table 7 and Action derived of recommendations for future work.

Table 8:

Table 7. Recommendations concerning the period covered by the report.

Recommendations concerning the period covered by the report.

Recom. N	Lead	Status	Observations
1	SCCH	Done	Annex to D1.5., submitted on M18
2	SCCH	Done	Architecture description in D5.1, submitted on M14

Due to these two recommendations, it was requested to allow a delay in 3 deliverables from M12 to M14, and issue them with standardized data. The PO answer was favourable to this extent.

Action derived of recommendations for future work.

Table 8. Action to complete along the project

Action	Lead	Due date	Status	Observations
1	SCCH	M18	Done	See annex A1 of this progress report
2	SCCH	M12-M36	In progress	On deliverables submitted from M12
3	ITU	M36	Pending	On *D5.5 Test and validation results* Due date M36
4	WU	M18	Done	See annex from D3.1 attached to this progress report

5	WU	M18	Done	See annex from D3.1 attached to this progress report
6	WU	M18	Done	See annex from D3.1 attached to this progress report
7	ITU	M18	In progress	On D4.1 *ML Driven Knowledge Extraction* delayed to M21
8	PRO	M19	In progress	On D7.1 *Integration Design* delayed to M22
9	SCCH	M12-M36	In progress	See SAB reviewed M12 and M18[4]
10	CORE	M18	Done	See D8.3 First Report on Dissemination activities & D8.8 Preliminary Exploitation Strategies and IPR Management
11	SDP	M18	Done	See D8.8 Preliminary Exploitation Strategies and IPR Management
12	CORE	M10-M36	In progress	See D8.3 First Report on Dissemination activities
13	CORE	M12-M36	In progress	See D8.3 First Report on Dissemination activities
14	SCCH	M18	Done	See D1.5 Envisioning report newly submitted on M18
15	SCCH	M10-M36	In progress	See Section4 of this deliverable D9.4
16	TIM	M10-M36	In progress	See section 1.2.1 of this deliverable D9.4
17	CORE	M10-M36	In progress	See D8.3 First Report on Dissemination activities
18	CORE	M10-M36	In progress	See D8.3 First Report on Dissemination activities
19	IDK	M36	Pending	On D5.4 *Open Source platform* Due date M36
20	SCCH	M18	Done	See section 4 of this deliverable D9.4
21	CORE	M10-M36	In progress	See D8.3 First Report on Dissemination activities
22	CORE	M10-M36	In progress	See D8.3 First Report on Dissemination activities

[4] See current composition of SAB in Annex 3

4 Update of the data management plan (if applicable)

The Data Management and Security Plan (D9.2) was submitted in March 2021 (M3). During M9 technical review the following recommendation was received:

"The use of data from industrial partners and its impact in the Data Management Plan needs to be more precisely defined."

The Data Management Plan has been updated in accordance with recommendation 15, action 20, producing a new and accurately defined summary of dataset as follows:

4.1 Annex of D9.2: Dataset summary

Annex: Dataset summary

1.1 Work package 1

1.1.1 ID1.1_RE_Questionaire

Description of dataset:	Set of questionaries that contain the functional requirements and quality attributes from Use case providers.
Objective of data:	The questionnaire was the basis for the requirements engineering within Teaming.AI and resulted to the RE document (Appendix to D1.5)
Handling of ethical issues:	Since no sensitive (personal) data, but only anonymous judgements regarding the technical functionality of the envisioned teaming platform has been collected, the data will not raise ethical questions.
Copyright and IPR:	Software competence center Hagenberg GmbH

Table 9. ID1.1_RE_Questionaire data summary

Origin of data	Re-use of existing data	Type of data	Format of data	Expected size of data	Receiver	Internal/ External	Data responsible	Public Yes/No

T1.5	*No*	*Set of Questionnaires*	*Word*	*<1MB*	*WP1-10*	*Internal*	*SCCH*	*No*

Version	Comments
1.0	Basis for RE document (D1.5, Annex 3)

1.2 Work package 2

1.2.1 ID2.1_UC2_Onto

Description of dataset: Ontologies for the representation of FMEA and parameter adjustment knowledge.

Objective of data: Represent FMEA and parameter adjustment knowledge for UC2

Handling of ethical issues: Dataset contains no personal data

Copyright and IPR: WU Vienna

Table 10. ID2.1_UC2_Onto data summary

Origin of data	Re-use of existing data	Type of data	Format of data	Expected size of data	Receiver	Internal/ External	Data responsible	Public Yes/No
T2.1	*Yes*	*Ontology/KG schema*	*owl*	*<1MB*	*WP2-7*	*Internal*	*WU*	*yes*

Version	Comments
1.0	used as supplementary material for a paper. Build upon public ontologies:

	• FMEA: https://w3id.org/teamingai/resources/ont/FMEA • Adjustment Protocol Ontology: https://w3id.org/teamingai/resources/ont/adjustmentProtocol

1.2.2 ID2.2_UC2_KG

Description of dataset: FMEA and parameter adjustment knowledge derived and transformed into KG representation from UC 2 documents provided by UC partner.

Objective of data: Represent FMEA and parameter adjustment knowledge for UC2

Handling of ethical issues: Dataset contains no personal data

Copyright and IPR: WU Vienna

Table 11. ID2.2_UC2_KG data summary

Origin of data	Re-use of existing data	Type of data	Format of data	Expected size of data	Receiver	Internal/ External	Data responsible	Public Yes/No
T2.1	*No*	*KG*	*ttl*	*<1MB*	*WP2-7*	*Internal*	*WU*	*no*

Version	Comments
1.0	Derived from FMEA sheets (xls) and parameter adjustment protocol (xls, doc) from IAL.

1.2.3 ID2.3_autoKG

Description of dataset: Production and quality checking process models in BPMN and knowledge graph representation.

Objective of data: Testing of automated process knowledge graph construction approach

Handling of ethical issues: Dataset contains no personal data

Copyright and IPR: WU Vienna

Table 12. ID2.3_autoKG data summary

Origin of data	Re-use of existing data	Type of data	Format of data	Expected size of data	Receiver	Internal/ External	Data responsible	Public Yes/No
T2.1	*Yes*	*Process model and RDF*	*Bpmn, rdf*	*8.3MB*	*WP2-7*	*Internal*	*WU*	*yes*

Version	Comments
1.0	Supplemental material for a conference paper describing an automated process knowledge graph construction approach. KG is based on bbo ontology (https://www.irit.fr/recherches/MELODI/ontologies/BBO/index-en.html). Public link: https://git.ai.wu.ac.at/teaming-ai/automated-business-process-knowledge-graph-construction-from-bpmn-models/-/tree/main/dexa

1.3 Work package 3

1.3.1 ID3.1_AIFB_KG

Description of dataset: Benchmark knowledge graph for structuring employees, working groups and publications of a university chair.

Objective of data: The graph was used to test the dynamic embedding framework NaviPy developed for WPs 2,3 and 4.

Handling of ethical issues: https://madoc.bib.uni-mannheim.de/41308/1/Ristoski_Datasets.pdf

Copyright and IPR: Publicly available benchmark dataset

Table 13. ID3.1_AIFB_KG data summary

Origin of data	Re-use of existing data	Type of data	Format of data	Expected size of data	Receiver	Internal/ External	Data responsible	Public Yes/No
UMA	*No*	*Knowledge Graph*	*ttl*	*5MB*	*WP2-4*	*External*	*UMA*	*yes*

Version	**Comments**
1.0	Details: https://madoc.bib.uni-mannheim.de/41308/1/Ristoski_Datasets.pdf

1.3.2 ID3.2_MUTAG_KG

Description of dataset: Benchmark knowledge graph consisting of chemical structures and bonds and their impacts on cancerogeneous illnesses.

Objective of data: The graph was used to test the dynamic embedding framework NaviPy developed for WPs 2,3 and 4.

Handling of ethical issues: https://madoc.bib.uni-mannheim.de/41308/1/Ristoski_Datasets.pdf

Copyright and IPR: Publicly available benchmark dataset

Table 14. ID3.2_MUTAG_KG data summary

Origin of data	Re-use of existing data	Type of data	Format of data	Expected size of data	Receiver	Internal/ External	Data responsible	Public Yes/No
UMA	*No*	*Knowledge Graph*	*ttl*	*7MB*	*WP2-4*	*External*	*UMA*	*yes*

Version	**Comments**

1.0	Details: https://madoc.bib.uni-mannheim.de/41308/1/Ristoski_Datasets.pdf

1.3.3 ID3.3_BGS_KG

Description of dataset: Benchmark knowledge graph which describes geological measurements in Great Britain and is used in to predict the lithogenesis of named rock units.

Objective of data: The graph was used to test the dynamic embedding framework NaviPy developed for WPs 2,3 and 4.

Handling of ethical issues: https://madoc.bib.uni-mannheim.de/41308/1/Ristoski_Datasets.pdf

Copyright and IPR: Publicly available benchmark dataset

Table 15. ID3.3_BGS_KG data summary

Origin of data	Re-use of existing data	Type of data	Format of data	Expected size of data	Receiver	Internal/ External	Data responsible	Public Yes/No
UMA	*No*	*Knowledge Graph*	*tsv*	*130MB*	*WP2-4*	*External*	*UMA*	*yes*

Version	Comments
1.0	Details: https://madoc.bib.uni-mannheim.de/41308/1/Ristoski_Datasets.pdf

1.3.4 ID3.4_AM_KG

Description of dataset: Benchmark knowledge graph which contains information about artifacts in a European museum. It has an artifact category, which serves as a prediction target.

Objective of data: The graph was used to test the dynamic embedding framework NaviPy developed for WPs 2,3 and 4.

Handling of ethical issues: https://madoc.bib.uni-mannheim.de/41308/1/Ristoski_Datasets.pdf

Copyright and IPR: Publicly available benchmark dataset

Table 16. ID3.4_AM_KG data summary

Origin of data	Re-use of existing data	Type of data	Format of data	Expected size of data	Receiver	Internal/ External	Data responsible	Public Yes/No
UMA	*No*	*Knowledge Graph*	*ttl*	*540MB*	*WP2-4*	*External*	*UMA*	*yes*

Version	Comments
1.0	Details: https://madoc.bib.uni-mannheim.de/41308/1/Ristoski_Datasets.pdf

1.4 Work package 7

1.4.1 ID7.1_FAR_ODS

Description of dataset: Table for the relations between the parameters and defect types which is summary of the internal training document.

Objective of data: Operator decision support.

Handling of ethical issues: Dataset contains no personal data

Copyright and IPR: Farplas

Table 17. ID7.1_FAR_ODS data summary

Origin of data	Re-use of existing data	Type of data	Format of data	Expected size of data	Receiver	Internal/ External	Data responsible	Public Yes/No
T7.1	*No*	*Guideline*	*xls*	*<1MB*	*WP2-7*	*Internal*	*FAR*	*no*

Version	**Comments**
1.0	

1.4.2 ID7.2_FAR_QI

Description of dataset: Sensor readings of the injection machines.

Objective of data: Quality inspection.

Handling of ethical issues: Dataset contains no personal data

Copyright and IPR: Farplas

Table 18. ID7.2_FAR_QI data summary

Origin of data	Re-use of existing data	Type of data	Format of data	Expected size of data	Receiver	Internal/ External	Data responsible	Public Yes/No
T7.1	*No*	*Set of numerical values*	*csv*	*5MB*	*WP2-7*	*Internal*	*FAR*	*no*

Version	**Comments**
1.0	

1.4.3 ID7.3_FAR_VQI

Description of dataset: Images of products with visible production errors.

Objective of data: Visual quality inspection.

Handling of ethical issues: Dataset contains no personal data

Copyright and IPR: Farplas

Table 19. ID7.3_FAR_VQI data summary

Origin of data	Re-use of existing data	Type of data	Format of data	Expected size of data	Receiver	Internal/ External	Data responsible	Public Yes/No
T7.1	*No*	*Set of images*	*jpg*	*450MB*	*WP2-7*	*Internal*	*FAR*	*no*

Version	Comments
1.0	

1.4.4 ID7.4_IAL_PIPP

Description of dataset: Full dataset of available parameters from the whole injection machine process (injection machine functional parameters and external parameters that affects the complete process). It is collected data from the injection machine process params, and sensors provided at mold for raw material monitorization.

Objective of data: The data it is used to monitor the status of all plastic injection process in order to optimize the whole process.

Handling of ethical issues: Dataset contains no personal data

Copyright and IPR: Industries Alegre

Table 20. ID7.4_IAL_PIPP data summary

Origin of data	Re-use of existing data	Type of data	Format of data	Expected size of data	Receiver	Internal/ External	Data responsible	Public Yes/No
T7.1	*No*	*Process parameters*	*Csv, json*	*<1GB*	*WP2-4*	*Internal*	*TYR*	*no*

Version	Comments
1.0	Collected by Tyris.AI

1.4.5 ID7.5_GOI_MaErp

Description of dataset: Data acquired from the machine (program name and tool number) and from ERP system (article id and working order) combined.

Objective of data: It is going to be used to train a Machine Learning model in order to predict the remaining time until next operator intervention is needed.

Handling of ethical issues: Dataset contains no personal data

Copyright and IPR: Goimek

Table 21. ID7.5_GOI_MaErp data summary

Origin of data	Re-use of existing data	Type of data	Format of data	Expected size of data	Receiver	Internal/ External	Data responsible	Public Yes/No

T7.1	*No*	*Machine/ERP data*	*Zip, Csv*	*1GB*	*WP3-4*	*Internal*	*GOI*	*no*

Version	**Comments**
1.0	Collected by Ideko

1.4.6 ID7.6_GOI_Vid

Description of dataset: Video Dataset from three wide-angle cameras, capturing the work at Goimek on a wind turbine housing. In the data, head, persons and ergonomic risks are annotated.

Objective of data: The data is collected to develop and train the ergonomic risk subsystem of the Teaming.AI platform

Handling of ethical issues: Timelex reviewed the collection and handling of data and considers the procedure as ethically and legally compliant with EU regulations. Final approval of internal ethics board is pending.

Copyright and IPR: Profactor

Table 22. ID7.6_GOI_Vid data summary

Origin of data	Re-use of existing data	Type of data	Format of data	Expected size of data	Receiver	Internal/ External	Data responsible	Public Yes/No
T7.1	*No*	*Video + Annotations*	*Motion Jpeg + COCO Annotation*	*100GB*	*WP4*	*Internal*	*PRO*	*no*

Version	**Comments**
1.0	

1.4.7 ID7.7_IAL_HF

Description of dataset: Interviews: Set of interviews to operators of "Industrias Alegre" performing different roles in the production process. Eye-tracker: Eye-tracking recordings of 1) description of the working area and processing methods and 2) examples of employees performing their tasks.

Objective of data: The data was obtained to assess and improve situational awareness of employees, as well as to identify useful information that could be provided by the human as an input for the AI. Eye-tracker: The data was obtained to have a contextualised view of the working area and processing methods and to have objective examples of the task performed by different operators from their own point of view. (D1.2 KPI specification).

Handling of ethical issues: Timelex reviewed the collection and handling of data and considers the procedure as ethically and legally compliant with EU regulations. Final approval of internal ethics board is pending.

Copyright and IPR: TU Dublin

Table 23. ID7.7_IAL_HF data summary

Origin of data	Re-use of existing data	Type of data	Format of data	Expected size of data	Receiver	Internal/ External	Data responsible	Public Yes/No
T7.3	*No*	Audio recordings, Eye-tracking data	*Wav, tobii.project*	*7.1GB*	*WP2-4*	*Internal*	*TUD*	*no*

Version	Comments
1.0	

1.4.8 ID7.8_GOI_HF

Description of dataset:	Interviews: Set of interviews to operators of “Goimek” performing different roles in the production process. Eye-tracker: Eye-tracking recordings of 1) description of the working area and processing methods and 2) examples of employees performing their tasks.
Objective of data:	The data was obtained to assess and improve situational awareness of employees, as well as to identify useful information that could be provided by the human as an input for the AI. Eye-tracker: The data was obtained to have a contextualised view of the working area and processing methods and to have objective examples of the task performed by different operators from their own point of view. (D1.2 KPI specification).
Handling of ethical issues:	Timelex reviewed the collection and handling of data and considers the procedure as ethically and legally compliant with EU regulations. Final approval of internal ethics board is pending.
Copyright and IPR:	TU Dublin

Table 24. ID7.8_GOI_HF data summary

Origin of data	Re-use of existing data	Type of data	Format of data	Expected size of data	Receiver	Internal/ External	Data responsible	Public Yes/No
T7.3	*No*	Audio recordings, Workload interviews, Eye-tracking data	*Wav, tobii.project*	*6GB*	*WP2-4*	*Internal*	*TUD*	*no*

Version	Comments
1.0	

Regarding Open-Source data:

During this first period (M1-M18), within the scope of task 7.1, datasets for each Use Case are being defined and it is planned to complete them at the end of the task(M19+3).

Within the scope of technical WPs, WP2-4 datasets have been defined and used in order to demonstrate each technical component. Coordinated by the exploitation manager, the consortium needs to agree which of those datasets could be considered as “open data” and be shared with the community, and which constraints or conditions could apply (e.g. in terms of licenses or usage restrictions). In principle, the datasets will not contain any personal data, since sharing such information could be privacy sensitive, and difficult to reconcile with the GDPR.

This process is ongoing and will be completed in the next period M19-M36.

The Quality Assurance Plan has been updated in accordance as follows:

Section and annex added:

3.2.3 Monitoring of the Use of Standards during Project Evolvement

Throughout the evolvement of the project, it is necessary to guarantee the highest standards and procedures not only for reporting but also for the whole process of method and software development. Therefore, the PC will establish and regularly update a Checklist for Monitoring the adopted Standards (Annex 6) that are used in the different WPs to facilitate uptake of project results. The review and updating of the checklist should be done at least every 6 months by the means of the GAM.

Annex 6: TEAMING.AI Checklist for the Use of Standards

1. Requirements specifications

- Specification of quality characteristics: ISO/IEC/IEEE 25010:2011 (SQuaRE) [1]
- Specification of functional requirements: ISO/IEC/IEEE 29148:2018 standard for systems and software engineering [2], RUPP Template [3]

2. Architecture description

- ISO/IEC 42010:2011 standard [4]

3. Workflow/process modelling

- BPMN 2.0 [5]

4. Conventions/Notations for knowledge representation

- W3C Standards: RDF / RDFS [6], OWL [7]
- Knowledge graph querying: SPARQL [8]

5. Conventions/Notations for ML model exchange

- ONNX [9]

6. Interoperability between Use Cases

- Encoding: UTF8, UTF16
- Message formats: Google Protocol Buffer Protocol (protobuf) [10], MQTT
- Data acquisition from target systems: OPC UA [11]

- Import data for the knowledge graph:
- RDF/RDFS [6], any notation
- XML (+ corresponding XML schema)
- Binary-Text Encoding: Base64
- Knowledge graph querying: SPARQL [8]

7. References

[1] International Organization for Standardization, “ISO/IEC/IEEE 25010:2011,” ISO/IEC/IEEE Systems and software engineering -- Systems and software Quality Requirements and Evaluation (SQuaRE) — System and software quality models, 2021. https://www.iso.org/standard/35733.html (accessed May 04, 2022).

[2] International Organization for Standardization, “ISO/IEC/IEEE 29148:2018,” ISO. https://www.iso.org/cms/render/live/en/sites/isoorg/contents/data/standard/07/20/72089.html (accessed May 12, 2022).

[3] C. Rupp and die Sophisten, Requirements-Engineering und -Management: Professionelle, iterative Anforderungsanalyse für die Praxis, 4., Aktualisierte und erweiterte Edition. München Wien: Carl Hanser Verlag GmbH & Co. KG, 2007.

[4] International Organization for Standardization, “ISO/IEC/IEEE 42010:2011,” Systems and software engineering — Architecture description, 2021. https://www.iso.org/cms/render/live/en/sites/isoorg/contents/data/standard/05/05/50508.html (accessed Feb. 22, 2022).

[5] M. Dumas, M. La Rosa, J. Mendling and H. A. Reijers, Fundamentals of Business Process Management, Second Edition, Springer, 2018.

[6] R. Guha and D. Brickley, "RDF schema 1.1," W3C recommendation, February 2014. [Online]. Available: https://www.w3.org/TR/2014/REC-rdf-schema-20140225/.

[7] "OWL 2 Web Ontology Language Document Overview (second edition)," W3C recommendation, December 2012. [Online]. Available: https://www.w3.org/TR/2012/REC-owl2-overview-20121211/.

[8] W3C Consortium, “SPARQL 1.1 Overview.” https://www.w3.org/TR/sparql11-overview/ (accessed Dec. 20, 2021).

[9] https://onnx.ai/

[10] Google, “Protocol Buffers,” Protocol Buffers, 2021. https://developers.google.com/protocol-buffers?hl=de (accessed Dec. Feb. 22, 2022).

[11] OPC Foundation, “What is OPC?,” OPC Foundation, 2008. https://opcfoundation.org/about/what-is-opc/ (accessed Feb. 22, 2022).

5 Deviations from Annex 1 and Annex 2 (if applicable)

The scope and objectives of the project are not affected by the following deviations.

5.1 Tasks

The main deviations, which were approved in the first and only amendment, were:

- Change of beneficiary from Tyris Software to Tyris AI, both from the same Group.
- Deliverables D1.1 Analysis report on human-AI teaming variants and D1.2 Catalogue of key performance indicators were moved from M5 to M6.
- WP1 was extended to M9, to allow D1.5 Envisioning report be submitted on M9.
- D1.5 was moved to M9, to include progress report and staff effort report with regards to the technical meeting to be held after M9. This change in D1.5 was requested by the Project Officer.

After M9 Technical review and also due to some technical difficulties to collect real data sets from use cases, the project has experienced some delays on its technical tasks that had lead to following deliverables due date delay.

- Due to M9 recommendations on the period covered by the report, it was requested to allow a delay in 2 deliverables from M12 to M14, and issue them with standardized data. The PO answer was favourable to this extent. D3.2 Teaming Model Initialization and D5.1 Software Architecture were submitted in M14.
- Due to the technical delay experienced in the last six months, Table 25 of new submission dates was proposed and accepted by the Project Officer.

Table 25. Deliverables delayed.

No	WP	Title	Due Date	New due date
D2.2	2	KG Population Methodology	M18	M21 (September 2022)
D2.3	2	Industrial KG	M20	M23 (November 2022)
D4.1	4	ML Driven Knowledge Extraction	M18	M21 (September 2022)
D4.2	4	ML Driven KG based Recommendation Systems	M20	M22 (October 2022)
D7.1	7	Use Case Digitalization	M19	M22 (October 2022)
D7.2	7	Use Case Commissioning	M21	M24 (December 2022)

- However, the Project Officer requested to deliver by the end of August an almost full version of deliverables D2.2 KG Population Methodology and D4.1 ML Driven Knowledge Extraction to be reviewed within 1st periodic review.

5.2 Use of resources

Table 26 shows figures of the person months used during the 18-month period of the Teaming.AI progress report.

Table 26. PM used in Period 1 vs project total.

		WP1	WP2	WP3	WP4	WP5	WP6	WP7	WP8	WP9			
Planned Progress (GANTT)		100%	74%	81%	49%	44%	6%	30%	50%	50%			
SCCH	Total PM	4	10	10	10	30	8	7	3	15	97		
	Planned PM M18	4,0	7,4	8,1	4,9	13,2	0,5	2,1	1,5	7,5	49,2	-1,7	PM
	Actual PM M18	4,32	3,49	13,66	0,33	16,47	0,04	0,35	1,47	7,37	47,5	-3%	
IDEA	Total PM	2	3	0	4	20	7	5	1	1	43		
	Planned PM M18	2,0	2,2	0,0	2,0	8,8	0,4	1,5	0,5	0,5	17,90	2,94	PM
	Actual PM M18	1,97	3,27	0,00	2,25	11,81	0,42	0,00	0,51	0,61	20,84	16%	
UMA	Total PM	2	7	14	4	12	5	7	1	1	53		
	Planned PM M18	2,0	5,2	11,3	2,0	5,3	0,3	2,1	0,5	0,5	29,2	-5,4	PM
	Actual PM M18	2,23	5,26	10,66	2,18	1,81	0,11	0,72	0,00	0,77	23,7	-19%	
IDK	Total PM	2	2	4	0	24	26	16	1	1	76		
	Planned PM M18	2,0	1,5	3,2	0,0	10,6	1,6	4,8	0,5	0,5	24,6	7,7	PM
	Actual PM M18	1,14	1,36	2,64	0,00	10,72	8,74	6,95	0,37	0,42	32,3	31%	
TYR	Total PM	2	5	3	10	15	10	17	1	1	64		
	Planned PM M18	2,00	3,70	2,43	4,90	6,60	0,60	5,10	0,50	0,50	26,3	4,25	PM
	Actual PM M18	1,71	3,92	2,97	8,44	5,33	1,30	5,86	0,49	0,56	30,6	16%	
IAL	Total PM	1	3	1	5	10	3	20	2	1	46		
	Planned PM M18	1,00	2,22	0,81	2,45	4,40	0,18	6,00	1,00	0,50	18,6	5,2	PM
	Actual PM M18	1,00	2,75	0,90	3,70	4,77	0,55	8,38	1,20	0,50	23,8	28%	
CORE	Total PM	1	0	0	0	0	0	3	33	1	38		
	Planned PM M18	1,00	0,00	0,00	0,00	0,00	0,00	0,90	16,50	0,50	18,9	0,2	PM
	Actual PM M18	0,50	0,00	0,00	0,00	0,00	0,00	0,94	17,44	0,24	19,1	1%	
ITU	Total PM	2	5	2	12	15	10	15	1	1	63		
	Planned PM M18	2,00	3,70	1,62	5,88	6,60	0,60	4,50	0,50	0,50	25,90	-4,8	PM
	Actual PM M18	2,20	3,47	1,58	10,04	1,88	0,53	0,93	0,16	0,30	21,09	-19%	
FAR	Total PM	1	3	1	5	10	3	20	1	1	45		
	Planned PM M18	1,00	2,22	0,81	2,45	4,40	0,18	6,00	0,50	0,50	18,1	3,5	PM
	Actual PM M18	1,01	1,71	0,51	2,39	4,51	0,00	10,93	0,02	0,43	21,5	19%	
SDP	Total PM	0	0	0	0	0	0	5	34	1	40		
	Planned PM M18	0,00	0,00	0,00	0,00	0,00	0,00	1,50	17,00	0,50	19,0	-0,4	PM
	Actual PM M18	0,00	0,00	0,00	0,00	0,00	0,00	1,63	16,49	0,50	18,6	-2%	
TIM	Total PM	3	0	0	0	0	2	4	7	1	17		
	Planned PM M18	3,0	0,0	0,0	0,0	0,0	0,1	1,2	3,5	0,5	8,3	-1,7	PM
	Actual PM M18	2,24	0,00	0,00	0,00	0,00	0,00	0,00	3,85	0,49	6,6	-21%	
GOI	Total PM	3	3	0	0	0	0	24	1	1	32		
	Planned PM M18	3,00	2,22	0,00	0,00	0,00	0,00	7,20	0,50	0,50	13,4	1,35	PM
	Actual PM M18	2,66	1,86	0,00	0,00	0,00	0,00	9,41	0,42	0,42	14,8	10%	
WU	Total PM	4	24	9	6	3	5	6	7	1	65		
	Planned PM M18	4,0	17,8	7,3	2,9	1,3	0,3	1,8	3,5	0,5	39,4	-4,6	PM
	Actual PM M18	4,14	17,92	6,79	4,08	0,43	0,36	0,79	0,06	0,22	34,8	-12%	
TUD	Total PM	3	0	2	0	7	5	10	1	1	29		
	Planned PM M18	3,0	0,0	1,6	0,0	3,1	0,3	3,0	0,5	0,5	12,0	1,33	PM
	Actual PM M18	3,1	0,0	1,4	0,0	2,4	2,6	2,9	0,3	0,7	13,3	11%	
PRO	Total PM	4	3	2	0	6	5	9	1	1	31		
	Planned PM M18	4,00	2,22	1,62	0,00	2,64	0,30	2,70	0,50	0,50	14,5	2,3	PM
	Actual PM M18	1,64	0,00	1,74	0,00	0,40	3,16	9,19	0,00	0,69	16,8	16%	
											335		
PM:	143 h									**Overall planned M18:**	335,3	10,1	PM
										Overall actual M18:	345,4	3%	

In general, the Teaming.AI project is well on track and total PM deviation is less than 5%. It is doubtless to mention that the technical progress has considered the current deviations of WP2-WP7. We are aware of the partners deviations, contemplating that during the work of each WP there is a high interdependence among them.

All costs incurred are lower than expected. The Cost Performance Index (CPI) indicates that the partners are being more efficient, except for WP3, WP4, WP6 and WP7 which are higher than expected.

WP8 is also slightly behind the plan but we expect higher activity in dissemination of the project results towards the end of the project that is currently not reflected in the plan as dissemination work is assumed to progress linearly. In addition, there are partner specific issues that are as follows:

- **IDK:** used **more** resources than expected due to a different internal calculation of IDEKO's planned PM distribution along work packages. The predicted PM effort for WP5, WP6 and WP7 from M1 to M18 is 10.6, 1.6 and 4.8 respectively, and varies by 9 PM plus Ideko's actual current effort.
- **IAL:** used **more** resources than expected due to difficulties to start with the development of the work package 5 and to get into the day-to-day dynamics. The deviation is of small quantities for each WP, which resulted in using 5,2 PM more than planned, which it is not a considerable deviation considering that WP5 depends on the previous WPs to proceed with its integration and implementation.
- **TIM:** used **less** resources than expected due to the assumption that resource expenditure should progress linearly in WP8 which doesn't fit in our case. Despite this, the deviation is very small of 1,7 PM less than expected.

We will monitor further progress closely and will adapt the project plan with M18 final costs if major deviations still exist due to the estimation of the last month.

5.2.1 Unforeseen subcontracting (if applicable)

Not applicable.

5.2.2 Unforeseen use of in kind contribution from third party against payment or free of charges (if applicable)

Not applicable.

6 Conclusions

Conclusions on WP1

The work package officially ended with M9. We currently have a good understanding of use case provider requirements and available data across all 3 use cases. Further specification of mockups and UI elements is foreseen in WP7. With the submission of the requirement engineering result as Annex to D1.5 all tasks have been completed successfully.

Conclusions on WP2

Key work in WP2 is on knowledge graph population and curation and on concepts for constructing and exploiting domain-specific knowledge graphs through data mapping and transformation, collaborative construction and integration. Current work is progressing well, however, WP2 has experienced a delay of 2-3 months due to unavailability and incompleteness of use case data. Contingency measurements taken in WP7 have resolved the issue but intensified work is needed to catch up with the project plan.

Conclusions on WP3

The Teaming Engine, including the Teaming Model as a core element, has been designed and its functioning is described in D3.1. A first analysis of meta-models and policies that form the basic input to the Teaming Model has been done for each use case. Results from D3.1 and D3.2 build the core concept for the Teaming.AI platform and are ready for implementation in upstream WPs. Major result is the release of a NaviPy Beta-Version for dynamizing existing Knowledge Graph embeddings that has been also presented at scientific conferences.

Conclusions on WP4

The lack of large amounts of data across all UCs is still a problem, but significant progress was made compared to previous period. Currently all UCs have some form of representational data that is sufficient for building model architectures and further developing ML methods. WP4 has experienced a delay of 2-3 months due to unavailability and incompleteness of use case data. Current efforts in WP7 in data collection should soon lead to a sufficient amount of data and facilitate ML model performance. Work on relational learning still needs further method development and a tighter integration with KGs from UCs.

Conclusions on WP5

First draft of the overall software architecture of the Teaming.AI platform is available and has been presented at the International Conference for Software Engineering. The implementation of the proof of concept based on the preliminary Teaming Model and initial technology stack evaluation is in progress. Further, we plan to validate the instantiation of the architecture meta-model, e.g., based on expert interviews, together with the use case providers. WP5 is delayed as a consequence of WP2 and WP4 delay. Now that the technical difficulties have been solved, and there is a very close follow up, we are confident to catch up the WP5 progress by M24.

Conclusions on WP6

WP6 has just started on month 13. This WP6 is the most affected by the general delay. However, the partners are advancing all possible activities to be able to speed up more easily when key information and outputs are available. Workshops at the General Assembly Meeting of M18 plus the at the workshop established tighter coordination between WP5, WP6 and WP7 based on a regular biweekly meeting schedule are contingency measures to resolve current delays in development.

Conclusions on WP7

Data integration possibilities for all three use cases have been analyzed and possible solutions for interfacing with the data are in development. Planning and installation of the tracking system for UC3 has been carried out and first batch of data is used for labelling ergonomic worker postures. Data collection is going on for all Use Cases. However, we needed to postpone deliverable D7.1 and D7.2 due to difficulties in sensor installations. During the General Assembly Meeting of M18, a dedicated workshop for UC integration work has been held, to accelerate further development.

Conclusions on WP8

Constant update of online media is the key to maintaining expectations on Teaming.AI. Organized contributions and updates are working quite smoothly and keeping good dissemination results. Social media channels creation and consequent publications are boosting the project´s presence in the media. Planned dissemination activities with other ICT 38 projects will help to grow the digital network even further. First market analysis conducted (see D8.5). Exploitation and IPR management still in an initial phase due to early phase of the project. However, SDP identifies the need to create awareness among the partners of IPR and dissemination procedures since any publications can compromise IPR novelty and inventive steps of other partners. Discussion about IPR novelty has been initiated at the GAM18 meeting.

Conclusions on WP9

All partners are collaborating smoothly. The current delays in data acquisition due to delays in sensor deployment will be soon resolved and the delay in upstream work packages is taken care of through a work plan adaptation. General work progress is on track and already achieved intermediate results are presented at several top scientific conferences. The project is likely to keep the timeline as initially proposed. On M12 some technical delay and its root causes were detected. A complete contingency measure plan was set up to solve the technical difficulties experienced. Many technic-specific workshops have been established for a better collaboration between partners. These measures have been proved to be effective and have boosted the project progress. Despite the COVID-19 pandemic situation, the whole consortium is making a huge effort to keep the pace foreseen in the Grant Agreement.

Conclusions on WP10

This work package is linked to Task 1.3 Modelling of policies and Task 8.5 Legal and ethical requirements definition. It has set the basis of this linked tasks. Each of these two tasks have a deliverable reporting the output of them. Deliverable D1.3 Teaming.AI Policies (M6) is a report on the legal and ethical rules and principles that must be taking into account during the project implementation and the design of the solutions. Deliverable D8.10 Legal and ethical requirements report (M36) is a report which will detail the legal requirements and provide ethical guidelines of the use of AI in manufacturing, and specifically the use of the Teaming.AI tools in practice.

7 A1. Background and foreground of D1.1, D1.2, D1.3, D1.4 and D3.1.

7.1 Deliverable 1.1 Analysis report on human-AI teaming variants

7.1.1 Background

The main purpose of D1.1, as the first deliverable in the Teaming.AI project, is to clearly describe the situation at the use case providers: Farplas, Industrial Alegre, and Goimek. Sections 3.1, 3.2, and 3.3 are the main contributions and the associated description of the current use cases and the problem definitions can be considered as background knowledge. Furthermore, the OLE for UC1 and UC2 are background knowledge too.

7.1.2 Foreground

Each use case description contains a subsection named "Vision with Teaming.AI". These can be seen as foreground knowledge, as they have been created in the course of the project. Further, Section 4 "Inter Use Case Findings" belongs to the foreground.

7.2 Deliverable 1.2 Catalogue of key performance indicators

The scope of D1.2 is to report about a catalogue of technical and organizational conditions, influencing factors and key performance indicators for successful human-AI teaming.

7.2.1 Background

There is a fast literature about how to assess impact on human factors, which is a key element for the evaluation of teaming activities. In Teaming.AI we concentrate on the following five important elements as background (see D1.2 and references within there):

1. Human Reliability Assessment: HEART (Human Error Assessment and Reduction Technique)
2. Workload Analysis: NASA TLX & other possible physiological measurements
3. Work Satisfaction: Hackman and Oldham's Motivating Potential Score
4. Physical Ergonomic Risk assessment methods: REBA, RULA, ART, MAC etc..
5. Evaluation of Human Machine Interface (ISO 11064 part 5)

In addition, we build upon the concept of teaming intelligence, introduced in Baker et al.[5], that highlights the need of coordination between team members. The work of Johnson et al.[6] analyzed the team member interdependencies further and structure them in their 4S Interdependence Framework for Understanding Teamwork, which was adapted as the basis for the KPI development in this deliverable.

7.2.2 Foreground

The deliverable provides an overview of KPIs and evaluation methods that are deployable in the context of the Teaming AI project. It provides an analysis of the rationale why those KPI have been selected and adapted to suit the needs of the use cases and of the Human machine collaboration nature of the tasks and the related critical elements to be assessed. This analysis provides an operationalization of the 4S model, where we match performance influencing factors to the elements of the 4S framework: state (preconditions), structure (task mapping swim lane), skills (competence, capacities), strategies (goals), respectively. Finally, we present a

[5] Baker, D. P., Day, R., & Salas, E. (2006). Teamwork as an essential component of high-reliability organizations. *Health services research*, *41*(4p2), 1576-1598.
[6] Johnson, M., & Vera, A. (2019). No AI is an island: the case for teaming intelligence. AI Magazine, 40(1), 16-28.

customisation of the KPIs identified to each use case and the specificity of their problem definitions.

7.3 Deliverable 1.3 TEAMING.AI policies

As recommended by the Commission in its M9 Project Review Report, a clearer distinction will be made in the documentation regarding the state of the art at the starting date of the project ("background") and the developments and innovations the consortium wishes to establish in the execution of the project or has established at the moment of delivery of this Deliverable 1.3 ("foreground").

7.3.1 Background

For the establishment of a baseline regarding the consortium's legal and ethical values to be taken into account in the execution of the project, the consortium has based itself on common European values, legal frameworks, and guidelines.

From a general research perspective, the consortium bases itself on Responsible Research and Innovation Guidelines. These guidelines have the goal of:

- Increasing ethical awareness;
- Improving relations with important groups and stakeholders;
- A more professionalised research management.

Within that framework, the consortium distinguishes the following legal sources, which are to be considered guiding principles:

- The General Data Protection Regulation (GDPR), 2016/679;
- The Product liability directive, 85/374/EEC;
- The 2021 Proposal for a Regulation laying down harmonised rules on artificial intelligence.

As a whole, these three legal sources contain the considerations made by the European legislators regarding the right to data protection and the general safety considerations regarding products and services, whether or not based on or linked with artificial intelligence.

In applying those legal frameworks, general ethical guidelines and papers discussing particular ethical perspectives were additionally taken into account, including without limitation additional RRI Guidelines, AI ethical guidelines, guidance from data protection authorities, etc. Those guidelines and papers are extensively set out in the bibliography under point 8, below.

For an interpretation of the legal frameworks, the guidelines, and the European values in general at the start of the project, this Deliverable 1.3, together with Deliverable 10.1, serves as the explanation of what the background of the project entails.

7.3.2 Foreground

The manner in which the consortium innovates upon to the current legal and ethical approaches, is twofold. First, the consortium has the goal of implementing the ethical and legal considerations identified in this Deliverable 1.3 in three distinct Use Cases, which each, in their own way, pose unique challenges from a legal and ethical perspective, that have not yet (or in a very limited fashion) seen application in the real world. Second, the consortium aims to implement into its artificial intelligence and Use Cases an element of auditable compliance. Auditable compliance refers to the ability of internal and external parties to be able to check whether or not the artificial intelligence and its specific application in the real word conform to specific standards set by the consortium in real-time and on an ongoing basis, through the software itself.

As regards the uniqueness of the three Use Cases, the first and the second Use Case have the goal of applying artificial intelligence in a teaming context with human participants in order to improve on existing manufacturing processes in factories. The consortium foresees that in applying artificial intelligence in this context, it will receive particular insights into the assessment and counterbalancing of particular challenges posed from a legal and ethical perspective, which are not yet part of the state of the art. As regards the third Use Case, the consortium foresees a more intensive management of legal and ethical requirements. The third Use Case has the added goal of partnering factory workers with an AI that indicates whether and when the factory worker finds itself in a bodily position that puts it in a short- or long-term risk of being harmed.

As regards the auditable compliance, the consortium aims to innovate by developing a novel ability to track, on an ongoing manner, whether or not an artificial intelligence application is implemented and performs in a manner that is compliant with predefined legal and ethical considerations.

7.4 Deliverable 1.4 Data requirements report

7.4.1 Background

Use of artificial intelligence in manufacturing applications gained significant attraction in recent years[7]. However, there are still no standards or best practices for data types and data collection methods for such applications that the community agrees upon. That being said, there are several significant previous works that study different data storage and model training methodologies for manufacturing applications, which can be used as a guideline when designing such a system. The work by Lee et al.[8] presents a data collection pipeline for predictive maintenance applications for manufacturing systems. Shafiq et al.[9] shows how computer integrated manufacturing systems might benefit from Internet of Things/Internet of Data. Qu et al.[10] expands upon these previous works and outlines several future trends in AI driven manufacturing data pipelines, including cloud computing and blockchain. Finally, a recent study Jung et al.[11] presents how data collected from injection machine can be used for quality of the produced results. From a critical point of view, although the material presented in these previous works can be taken as a starting point for building data collection and storage systems for AI driven manufacturing systems, there are still a lot of open issues, especially on deciding on the modality and granularity of data required for such applications. Moreover, previous work barely addresses how to incorporate domain knowledge and expert opinions to such architectures, which is a central topic in Teaming.AI project.

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7.4.2 Foreground

In this deliverable, we presented the available data across use cases and provided comments on the usability of this data for building the Teaming engine. We conclude with further observations and future tasks involving data collection:

- All use case providers have established frameworks for collecting and managing data, which will be of tremendous help in building machine learning algorithms in WP4 and fueling KG construction in WP2-WP3.
- Each use case involves data at different resolutions. All of them involve numeric time-series data that can be obtained from machines involved in the production process, in addition to static parameters that describe particular settings of the process. It is assumed that these time series data will be integral in development of machine learning algorithms in WP4.
- Two of the use cases also provide text data that outline guidelines on fault diagnosis and problem solving. It is assumed that these text data will be useful for KG construction algorithms to be developed in WP2 and WP3.
- Each use case provider has ongoing plans on increasing the fidelity and resolution of the current data collection process, in addition to integration of new data sources.
- The further requirements on data collection for each use case will be finalized by other WPs, as the development of Teaming engine progresses.

7.5 Deliverable 3.1 Teaming Model

7.5.1 Background

D3.1 builds upon state-of-the-art methods and standards, most notably W3C standards and concepts developed by the Semantic Web research community on the one hand, and Business Process Modeling formalisms and languages (BPMN) on the other hand. Section 3 provides a background for the remainder of the deliverable and summarizes the state-of-the-art in knowledge graphs and business process modeling and mining from a project perspective in order to provide a foundation for the development of the teaming model. The section also outlines a knowledge graph layering approach developed specifically for Teaming.ai as a background in Section 3.1.3 – this layering approach is covered in detail in a separate deliverable (D 2.1).

The teaming model also builds upon the state of the art in the following ways:

- It relies on established standards (RDF, OWL-S, BPMN)
- The idea of Concrete and abstract activities was adopted and extended from [36]

7.5.2 Foreground

- Section 4 covers the results of the requirements elicitation process for the teaming model
- Section 5 first introduces the teaming model (Proces, Activity, Policy, Event models) developed for Teaming.ai to coordinate the cooperation of humans and AI agents in manufacturing environments and then discusses its enactment and integration in the Teaming.ai architecture.
- Section 6 documents the software prototype developed

8 A2. Annex of D3.1

There are 3 actions related to an Annex of D3.1. This annex should be included in D9.4 as D3.1 is already approved. The full text of the recommendation and the answer provided is in the text attached.

1. In order to clarify this design decision, we will provide an additional discussion of pro/cons as an Annex in D3.1 (action 4)
2. Design decisions for the notion of control flow will be clarified in an Annex of D3.1. (action 5)
3. Design decisions for the notion of digital twin will be clarified in an Annex of D3.1 (action 6)

Human-AI Teaming Platform for Maintaining and Evolving AI Systems in Manufacturing

D 3.1 Teaming Model - Clarifications

Deliverable Lead	WU Wien
Deliverable due date	September 30, 2021
Actual submission date	September 30, 2021
Version	1.1

A2 Annex III: Clarifications

10.1 Coordination Mechanisms

This annex discusses design options and decisions regarding centralized/decentralized control and support for coordination, cooperation, and collaboration. The high-level coordination mechanism described in Section 5.5 is based on a central component, the **Teaming Engine**, which acts as an autonomic manager that monitors the runtime processes. We chose this approach after careful deliberation about the general benefits and drawbacks of various design alternatives and implementation options, which we summarize in the following.

Two general types of high-level coordination strategies we considered are orchestration and choreography. **Orchestration** describes the scenario when the coordination between different entities, e.g., software services, is performed via a central coordinator. **Choreography** describes the scenario when the entities work independently but coordinate directly via messages or events without requiring a coordinating unit.

Each of these approaches has advantages and disadvantages. Whereas orchestration provides a high level of **control** via the central coordinator, this central coordinator is also a **single point of failure** and a **scalability** bottleneck. The choreography approach does not suffer from this single point of failure. However, choreography requires multiple point-to-point communications that increase the complexity of the system, the complexity of the development, and the complexity of adapting the system.

Another consideration in the selection of an appropriate coordination mechanism was the availability of **industrial grade execution engines**. Several orchestration engines are developed and used in industry, e.g., Camunda[12] or FireStart[13]. Moreover, several **distributed orchestration engines** evolved in recent years to compensate the single point of failure and scalability limitations of the coordinating unit. Camunda Zebee[14], for instance, is a distributed orchestration engine for business processes designed in BPMN 2.0. Other highly scalable distributed orchestration engines, developed and used by leading cloud-based providers, are, e.g., Uber's Cadence[15], Netflix Conductor[16] or Amazon Step Functions[17].

Because **choreography** is based on the principle of direct communication between services, **fewer engines exist**. One example of a choreography-based engine is PHILharmonicFlow (Andrews, Steinau, & Reichert, Enabling runtime flexibility in data-centric and data-driven process execution engines, 2021; Andrews, Steinau, & Reichert, Engineering a highly scalable object-aware process management engine using distributed microservices, 2018), a scalable

[12] https://camunda.com
[13] https://www.firestart.com/about/
[14] https://camunda.com/products/cloud/workflow-engine/
[15] https://cadenceworkflow.io
[16] https://netflix.github.io/conductor/
[17] https://docs.aws.amazon.com/step-functions/latest/dg/welcome.html

object-aware process management engine that uses distributed software services on cloud resources. As an underlying architecture, PHILharmonicFlow uses the **actor model**, where each microservice is an actor and connected to different other actors according to a data model. While this actor model allows for high scalability, integrating new objects into the data model is computationally very costly. Furthermore, each actor must be aware of the process structure since the actors directly communicate with each other.

For Teaming.AI, we decided to use an **orchestration approach** mainly due to its **flexibility** in the terms of coordinating the work between services. This flexibility is provided at design time and during runtime when a process has to be adapted. Note that the Teaming engine will orchestrate high-level teaming processes that monitor the production execution environment and use the teaming model to plan and execute specific adaptation actions (cf. Section 5.5.1, Figure 12). It will not, in any of the use case scenarios considered in TEAMING.AI, control low-level production processes and process any raw events directly. This limits the scalability requirements and potential impact of bottlenecks and failures.

To further limit such potential negative effects, we opted for an approach that can be implemented as a distributed orchestration to avoid a single point of failure and scalability bottlenecks. As stated above, several industrial leading cloud vendors -- e.g., Netflix, Uber, and Amazon – rely on distributed orchestration engines for their service operations, which inspires confidence in the scalability of the approach. Specifically, we decided to use Camunda Zebee as the orchestration engine for our prototype due to the support of processes designed in BPMN 2.0, which (Bergs, Klink, Schraknepper, & Augspurger, 2021) is the de-facto standard in the industry and has also been used in the manufacturing domain (Ahn & Chang, 2018; Mangler, Pauker, Rinderle-Ma, & Ehrendorfer, 2019; Mazzola, Kapahnke, Waibel, Hochreiner, & Klusch) for designing processes.

10.2 Imperative vs. Declarative Modeling and Control Flow

TEAMING.AI will use an **imperative process modeling approach based on BPMN**, which will be extended to incorporate teaming-specific aspects. Section 3 of this deliverable discusses the conceptual differences and relative merits of declarative and imperative process modeling approaches in general terms and covers some formalisms for declarative and imperative modeling.

In the following, we clarify and lay out our criteria for the design decisions regarding (i) imperative/declarative process models and (ii) control flow between the performance domain (people and operational technology) and the enactment domain (the enacting teaming engine).

Imperative vs. declarative process models

We considered both modeling paradigms as options for the teaming model and carefully deliberated their relative merits. In this process, we found that the requirements are not uniform across use cases. Whereas some – e.g., diagnostic – use cases would benefit more strongly from a more flexible, sequentially less restrictive and more circumstantially and context-driven declarative modeling approach, it was necessary to find a common modeling approach that is viable across all use cases.

Key considerations in this design choice included flexibility, compactness, human understandability and ability to anticipate and retrace model enactments, maintainability, suitability for policy modeling and checking, architectural integration, and implementation viability.

A key benefit of declarative modeling approaches, which are based on the idea of specifying only constraints over the possible actions and allow much more flexible execution, is that the paradigm is well-suited for highly **volatile environments** (Haisjackl, et al., 2013). This characteristic is beneficial in the context of TEAMING.AI in that no design-time commitment to a static sequential process structure is necessary. This is useful for unstructured tasks characterized by a high degree of variability. At a fine-granular level, for instance, diagnostic tasks carried out by domain experts with the help of analytic components will, for instance result in highly heterogeneous execution traces that cannot easily be represented in an imperative model. From this perspective, we therefore initially favored a declarative modeling approach.

From an **architectural perspective**, an important consideration was the ability to integrate the modeling approach into a knowledge graph framework. Here, a declarative approach would be somewhat more consistent with the open world assumption commonly used in Semantic Web/KG modeling. In prior work, we already proposed a method to integrate declarative process models by translating DECLARE constraints into SHACL constraints that can be checked against process traces in a knowledge graph (Di Ciccio, Ekaputra, Cecconi, Ekelhart, & Kiesling, 2019). We considered adapting this process modeling approach for the teaming model, but found that the modeling approach to be difficult to convey in discussions with use case partners, who considered specifying teaming processes in the outside-to-inside approach of defining processes indirectly in terms of their essential characteristics (Pichler, Weber, Zugal, Mendling, & Reijers, 2011) difficult. This finding is consistent with empirical research results that showed that declarative modeling pose challenges in **human understanding** (Haisjackl, et al., 2013) (Haisjackl, et al., 2014). Whereas establishing circumstantial information is typically easier in more declarative process models, imperative process models make it easier to establish sequential information (Fahland, et al., 2009). We found in our modeling workshops that practitioners tended to think of teaming processes in sequential terms. As sequence is a hidden dependency in declarative languages, adapting to this paradigm requires a change in thinking, which tended to be mentally difficult, making it difficult to anticipate the behavior at execution time, as the circumstantial context is difficult to anticipate.

This will then also be reflected in the **maintainability** of the teaming models in that circumstantial changes will be more difficult to apply to imperative models whereas sequential changes are more difficult to apply in declarative models (Fahland, et al., 2009).

Furthermore, even though describing teaming processes in terms of declarative constraints would allow for more **flexibility** for contextual adaptation, it would also introduce additional modeling challenges -- such as ensuring the specification of a consistent and complete set of constraints necessary so that the process will be enacted *as intended* (which may not necessarily correspond to stakeholder expectations and the model *as specified*). Consequently, human stakeholders may find it difficult to anticipate teaming model behavior at runtime given a set of declarative constraints, which in turn could impair **trust in the enacted Teaming processes**. Given that understandability and clear policy specification are key design priorities in the project, this was a strong factor that favored an imperative modeling approach.

Another aspect considered was that the typical teaming processes we encountered in the context of the use cases so far could easily described in imperative terms. The **principle of minimal description length** (Barron, Rissanen, & Yu, 1998) therefore also favors an imperative modeling approach. Although this introduces limitations due to the rigid sequential structure that does not favor contextual adaptation, we found that the required **flexibility** can be reintroduced in imperative modeling environments by decoupling independent and autonomous, but imperatively structured processes through (i) message flows and events, (ii) abstract activities. The first technique can be used to loosely couple imperative sub-models that explicitly prescribe workflows through messages and events – i.e., sub-models can listen for events and define conditions for their execution. Abstract activities that make decisions on who will be responsible for a given activity at execution time based on the context (e.g., human or AI agent) also add flexibility where necessary without the necessity to subscribe to a declarative paradigm.

Overall, we therefore chose an imperative modeling paradigm as a foundation, but consider the imperative-declarative spectrum as a continuum in the sense that declarative aspects can be introduced where needed – e.g., through policy reasoning and loose coupling of sub-processes with events and declarative rules defined on these events. This should result in a good tradeoff between manageability, flexibility, understandability, and **practical viability**.

Regarding the latter, a final consideration was that declarative models are less commonly used to specify process models and that they are hence typically not readily supported by execution engines (Soffer, et al., 2019). Available process engines typically rely on common process models such as BPMN that explicitly specify the possible sequence of activities to be followed in imperative terms.

Overall, these considerations resulted in the choice of an imperative approach.

Control flow between the performance and enactment domain

As discussed in Section 5.5, the teaming model will be enacted by the Teaming engine, which will monitor the execution environment, track the dynamic context of the enacted teaming process in the production environment, and apply policies to orchestrate teaming processes. These teaming processes in the "enactment domain" are intentionally decoupled from the operational environment in that the Teaming engine does not orchestrate any production processes. Instead, it acts as an autonomic manager (Weyns, 2017) (Chess D., 2003) that monitors the production execution environment, analyzes up-to-date knowledge to determine whether there is a need for adaptation, and uses the teaming model to plan and execute adaptation actions.

These adaptation actions are defined in the enactment domain and we choose not to model an explicit control flow (or "sequence flow" in BPMN terms (OMG, 2011)) between the "performance domain" – i.e., the operational domain of production processes being executed on the shop floor (people and operational technology) and the Teaming model enactment domain. Such explicit sequence flow modeling of the whole production process and management environment in a monolithic imperative model across these domains would create complex dependencies, would be difficult to adapt, and infeasible to implement in many real-life production settings due to reliability and safety concerns.

Instead, the design outlined in the deliverable considers the teaming process a managing process that sits on top of, but does not directly interfere with production processes through control flow interactions. In Business Process Modeling (BPMN) terms, these domains are linked not through an explicit sequence flow, but through asynchronous messaging, i.e., message flows. These flows are used in BPMN to model message passing between concurrent processes in independent organizations (pools) and are a very good fit to model interactions between what we consider autonomous systems. The production system as the managed system will be adapted (e.g., by changing machine parameters) based on observed events in the operational environment (e.g., quality issues detected through automated visual inspection). In UC 2, for instance, the teaming model will coordinate human expert analyses and automated analytic components (rule-based symbolic and/or machine learning components) to derive suitable machine parameter recommendations. However, it will still be up to the operator on the shop floor to implement these changes. In a similar vein, feedback on ergonomic risks detected and delivered to shop floor operators in UC3 should lead them to adaptation their posture, but this does not constitute a direct control flow between the performance and enactment domains.

This design decision to strictly separate the Teaming process as a managing process (that is internally coordinated through sequence flows) from the managed operational production processes helps to untangle otherwise complex control flow patterns, fosters flexibility, supports a clean separation of concerns, and ensures viability of the approach in real-world production settings. Furthermore, it is also consistent with our design decision to conceive the knowledge graph as a “digital shadow” rather than a “digital twin”, i.e., changes in the knowledge graph are not reflected in automated changes in the production system level, which would require a direct control flow between these levels (also cf. the following appendix).

10.3 Digital Twin vs. Digital Shadow

In Section 5.5.2 of the deliverable, we state that the knowledge graph in the TEAMING.AI system will act as a single integrated data store that captures a **digital semantic shadow** of the production system. In the following, we clarify this statement, elaborate on the differences between **Digital Twin** and **Digital Shadow** concepts, and motivate our choice of modeling approach in the context of the project. Specific knowledge graph modeling aspects pertaining to the modeling of production systems (i.e., how the digital shadow will be defined and modeled) will also be discussed in WP2 deliverables. In the following, we focus on clarifying how the concept relates to the Teaming model proposed in this deliverable.

A key idea of the TEAMING.AI project is to enable human-AI collaboration in a manufacturing context. This inherently creates a need to represent products and production systems and their characteristics. Such representation of physical objects is central to the notion of a Digital Twin, which in manufacturing is considered a virtual counterpart of the product (Schroeder, Steinmetz, Pereira, & Espindola, 2016)and/or production system (Rosen, Wichert, von Lo, & Bettenhausen, 2015) across their lifecycle. In the TEAMING.AI scenarios, the focus is mainly on the representation of production system equipment during operations (e.g., injection moulding machines in UCs 1 and 2, milling machines in UC 3 etc.). The representation of products (e.g., plastic parts for the automotive industry, gear components for wind mills) may partly also be necessary, but is less central to the overall approach.

Whereas Digital Twins aim for a detailed representation of the state of the physical object, ideally at a level of granularity that enables a complete simulation of its behavior – we found that such a detailed representation in a complete Digital Twin of the production system is typically not necessary and useful in TEAMING.AI scenarios. The teaming model defined in this deliverable typically operates on a more abstract level and coordinates the actions of human and automated agents on a less granular level. Therefore, the detailed modeling and simulation of physical processes is beyond the scope of the TEAMING.AI platform.

Another key characteristic of digital twins is that data flows between physical and digital object are fully integrated in both directions (Bergs, Klink, Schraknepper, & Augspurger, 2021). The notion of such bidirectional mirroring – i.e., changes in the knowledge graph being automatically mirrored in the physical objects it refers to -- is interesting in various use cases (e.g., control parameter changes made by human and/or automated learning agents directly in the knowledge graph could automatically be executed on the shop floor). However, none of the use cases requires such bi-directional synchronization of state changes. In fact, it would be exceedingly difficult to retrofit existing production systems to automatically reflect such state changes in the knowledge graph. Even though such technical challenges can be overcome – e.g., thorough appropriate Asset Administration shells – a fully mirrored Digital Twin in a knowledge graph would also raise safety concerns and violate restrictions imposed by machine manufacturers in the use cases (e.g., parameter adjustments cannot be performed in a fully automated manner according to operational guidelines).

For these reasons, we chose to base our approach upon the notion of a Digital Shadow (Kritzinger, Karner, Traar, & Henjes, 2018) which, in contrast to a digital twin, is a model that is fed by a one-way data flow with the state of an existing physical object. In this model, a change in state of the physical object leads to a change in the digital object, but not vice versa. Consequently, the KG is partly a digital semantic shadow of production assets and their describable and variable properties across their lifetime. Facts in the knowledge graph therefore represent status data from the shop floor by relating measurements to a specific asset at a specific instant in time – consistent with the notion of a semantic shadow (Bergs, Klink, Schraknepper, & Augspurger, 2021). Our notion of a digital semantic shadow is also consistent with the common lifecycle perspective [Bergs] in that the knowledge graph will capture an up-to-date representation of a real asset in a virtual space.

This model fits the requirements in TEAMING.AI well, as our aim here is not to produce an accurate and detailed image of all low-level processes in production, but to monitor relevant aspects. Note that the precise structure and resolution of the digital shadow will depend on the application and is not universally valid (cf. (Bergs, Klink, Schraknepper, & Augspurger, 2021)). The modeling of production system assets is also a consideration in WP2 (Knowledge -Graph) and we found that the digital shadow concept is suitable for the modelling of teaming aspects in manufacturing.

A2 Annex III Bibliography

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9 A3. Current SAB composition

M12 & M18 current composition in Table 27, as member of SAB have not changed.

Table 27. Scientific Advisory Board

Member	Selection criteria, justification
Daniel Calvo Head of Artificial Intelligence and Robotics Atos Research and Innovation	Participating in AI4EU project
Sergio Gusmeroli Research Coordinator Politecnico di Milano, Department of Management, Economics and Industrial Engineering	Coordinator of DIH4AI AI-on-demand-Platform, coordinator of I4MS BEinCPPS project, member of XMANAI ICT-38 project
Santiago Muiños Landin Artificial Intelligence and Data Analytics department Team leader AIMEN Technology Centre	Member of MAS4AI ICT-38 project
Gabriel González Castañé, PhD, MSc, Eng, Senior Research Coordinator, Insight Centre for Data Analytics Western Gateway Building, University College Cork, Cork, IRELAND.	AI4EU Ecosystem, linkage to other initiatives, projects, other parts of the European AI Ecosystem

10 A4 Addition on ethical template Gender considerations

10.1 Gender considerations in the research and development team

The consortium is aware of the fact that increasing diversity of a workforce developing AI systems will reduce the risk that the AI systems generate discriminatory and unfair outcomes, thus ensuring that their benefits are more widely shared. The consortium is also aware of the persistent and structural gap among AI professionals with career trajectories being differentiated by gender. This inevitable gap is also visible in the different profiles found in the consortium project member and may in theory lead to problematic results in the artificial intelligence created by the consortium.

Notwithstanding the previous, the identified gender-risk is somewhat mitigated due to the specific nature of the Teaming.AI project. The gender considerations, without underestimating their importance and value to the development of AI in general, were therefore taken into account only to a lesser extent when composing the teams of the participating members to the consortium. The members preferred to place the emphasis on academic and professional qualifications rather than gender equality as an aim in and of itself, meaning that in a research community consisting mostly out of men, the result is that mostly men are participating as researchers.

The specific nature of the Teaming.AI project is best described using the specific use cases as a basis. The Teaming.AI project mainly works with gender-neutral technologies and machinery that perform in a purely technical manner in order to e.g., improve the production processes. The human factor is generally limited to guiding the machines to perform their tasks. The participating humans are not in any impacted by the functioning of the factory machines. In contrast, however, use case 3 ('**UC3**') contains a slightly stronger emphasis on the human element in the teaming of humans and AI. For UC3 specifically the consortium is aware that it was unable to recruit a sufficient number of female researchers and the, albeit limited – as expressed below, gender risk posed by this deficiency is well-known.

Taking into account this gender risk, the consortium deems that the risk is to a large extent mitigated due to (i) the internal awareness of the gender risk, (ii) the limited human factor in the use cases and (iii) the fact that the final product should be stripped from all data and should be applicable to other technologies, irrespective of gender. As such, the gender risks in the research and development team should be considered minimal to low.

10.2 Gender considerations in the use case

UC3 aims to research both the the ability of AI to improve manufacturing processes, as well as the use of AI for detecting and improving ergonomics at the factory work floor. Due to the limited scale of UC3, the consortium was unable to define different gender groups within the tracked factory workers, seeing as also in this sector there exists a rather large gender gap and UC3 is performed at a single factory. The consortium is aware of the fact that gender-specific implications may impact the findings in UC3 as well as the developed AI.

In addition, the consortium makes use of gender-neutral technologies and gender-neutral research (e.g., REBA and RULA) for conducting UC3, which do not distinguish based on gender.

Finally, the gender-risk in the Teaming.AI project should be limited to UC3 and should not be part of the final deliverables of the Teaming.AI project, seeing as the final deliverables should be stripped from all data and should be applicable to other technologies, irrespective of gender.

To conclude, the consortium deems the gender risks are to a large extent mitigated due to (i) internal awareness of the gender risk, (ii) the fact that the consortium uses, where possible, gender neutral technologies and research to build its AI and own research, and (iii) the fact that the final product should be stripped from all data and should be applicable to other technologies, irrespective of gender. As such, the gender risks in UC3 should be considered minimal to low.

11 A5 New deliverable template

teaming.ai

Human-AI Teaming Platform for Maintaining and Evolving AI Systems in Manufacturing

Replace with Deliverable number and name

Deliverable Lead	Partner Name
Deliverable due date	xx/xx/202x
Actual submission date	xx/xx/202x
Version	x.x

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Review status	☐ Draft ☐ WP leader accepted ☐ Coordinator accepted
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1.1			
2.0			
2.1			
3.0			
3.1			

List of contents

List of Figures

List of Tables

1 Abstract / Executive Summary

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2 Introduction

Commented [IF3]: This section is mandatory. Describe the background of the deliverable, which is the SotA within the project, the problem you want to address, where are you going to do it (WP and tasks) and how (concepts and techniques).
Material which would have formed part of the performer's normal output regardless of project participation should be classified as "BACKGROUND"

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2.2 WP and Tasks related with the deliverable

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2.3 Concepts and techniques

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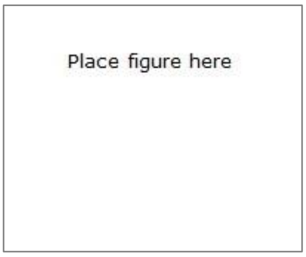

Figure 1: lorem ipsum

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Table 1: Lorem Ipsum

Title	Title	Title	Title

Table 2: Lorem Ipsum

Title	Title	Title	Title
Title			
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5 Conclusions

Commented [IF5]: This section is mandatory.
A description of the foreground achieved **must** be included. *FOREGROUND is material that has originated after the inception of the project and has been undertaken solely because of the performer's participation in the project.*

6 Glossary

Commented [IF6]: This section is mandatory

Bibliography

7 Annex I

8 Annex II