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FINAL Project Report

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Final Report

Introduction

This document represents the Deliverable 8.8 Final Project Report of the H2020 project "FACTS4WORKERS – Worker Centric Workplaces in Smart Factories" (FoF 2014/636778). It reports and explains the activities, the work done, the archived results and the impact of the project.

The reported period is the complete project duration from December 1, 2014 to November 31, 2018. This report summarizes and supplements the content of the Deliverables 8.5 – 8.7, Periodic report (1), (2) and (3).

It is the intention of this report to provide a brief and comprehensive overview on the work conducted, methodologies, results and achievements of the project without going into detail. For more detailed information, please consult the relevant deliverables.

Keywords

Requirement Analysis, Digital Work Design, DWD, Augmented Reality, Smart Glasses, smart watches, smart factories, Industrie 4.0, Industry4.0, CPPS, wearables, Factories of the future, FoF, H2020, REST, RESTdesc, API, blue collar workers

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

1.1 Objectives

FACTS4WORKERS´ primary goal is to develop, pilot and evaluate a worker-centred smart factory solution connecting workforce, organisation, management and technology to support new models for work optimisation and utilisation of production systems from a knowledge-based perspective. Advancement will be gained through integrating several building blocks from a flexible smart factory infrastructure, focusing on workers' needs and being supported by organisational measures and change management. FACTS4WORKERS will increase problem-solving and innovation skills, cognitive job satisfaction and average worker productivity for workers participating in industrial pilots.

Moreover, FACTS4WORKER's objectives in terms of measurable indicators are:

- **O1:** To **increase problem-solving and innovation skills** of workers participating in the pilots HIR, THK, SCA, HID, EMO, and THO, as measured by e.g. innovation capability test scores.

- **O2:** To **increase cognitive job satisfaction** of workers participating in the pilots, as measured by an increased score on relevant factors on a Spector Job Satisfaction Survey (JSS), and to improve their working conditions in terms of safety, work organisation and well-being.

- **O3:** To **increase average worker productivity** by 10% for workers participating in pilots, as measured by a mix of proven and newly developed metrics enabled by the smart factory concept and the evolving role of the worker.

- **O4**: To achieve **TRL 5-7** on a number of worker-centric solutions through which workers become the smart element in smart factories, interacting by deploying a flexible smart factory infrastructure.

The solutions are developed according to the following four industrial challenges which are generalisable to manufacturing in general: personalised augmented operator (IC1), worked-centric rich-media knowledge sharing/management (IC2), self-learning manufacturing workplaces (IC3) and in-situ mobile learning in the production (IC4).

- **IC1: Personalised augmented operator** are workers using augmented reality (AR) tools through which they get an immediate, specific, visualized, and personalized provision of information at the shop-floor-level, which can be configured according to their needs, roles and preferences.

- **IC2: Worked-centric rich-media knowledge sharing/management**:   ICT adopted in factories is neither successful in capturing knowledge, nor do they support social interaction and learning. Such KMS are usually developed for office environments, but shop-floor workers have different needs.

- **IC3: Self-learning manufacturing workplaces** are established through linking heterogeneous information sources from the worker's environment and beyond, and extracting patterns of successful production, transferring the result as decision-relevant knowledge to the worker.

- **IC4: In-situ mobile learning in the production**, will develop and demonstrate an on the job learning environment for shop floor workers using rich media through the KMS, which is especially valuable for SME.
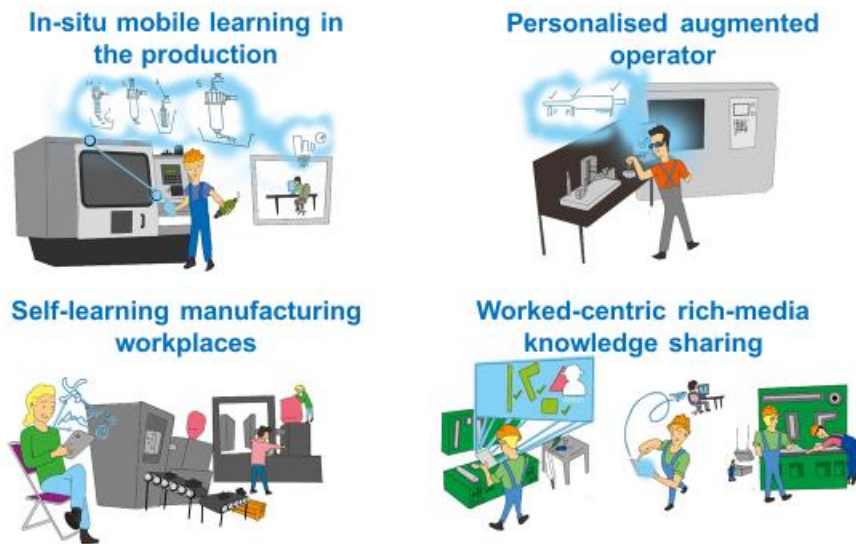
Figure 1: The four industrial challenges

1.2   Explanation of work carried per WP

1.2.1   Work Package 1 – Worker needs, organizational requirements, and Industrial Challenges

Analyse worker needs and organisational requirements

FACTS4WORKERS started with capturing workers´ and organizations' needs and requirements for information and knowledge-based support in manufacturing. Therefore, WP1 started to explore the practices of workers and the contexts of organizations at the six industrial partners. During several visits to the industrial partners, focus group sessions and interviews were conducted, as well as photos and videos. From this we developed problem scenarios (how do workers currently perform their work), activity scenarios (what are problems and suggestions how to support workers), personas (fictional worker role models in order to better understand their requirements), mockups & demonstrators (screen illustrations) as well as collaboration patterns (high level interactions with intended smart factory solutions). These artefacts were embedded in different contexts-of-use (characteristics of the intended smart factory solution) at six industrial partners. The identification of workers' practices and the contexts of organizations at our six industrial partners are described in **Deliverable 1.1: Captured and structured practices of workers and contexts of organisations**.
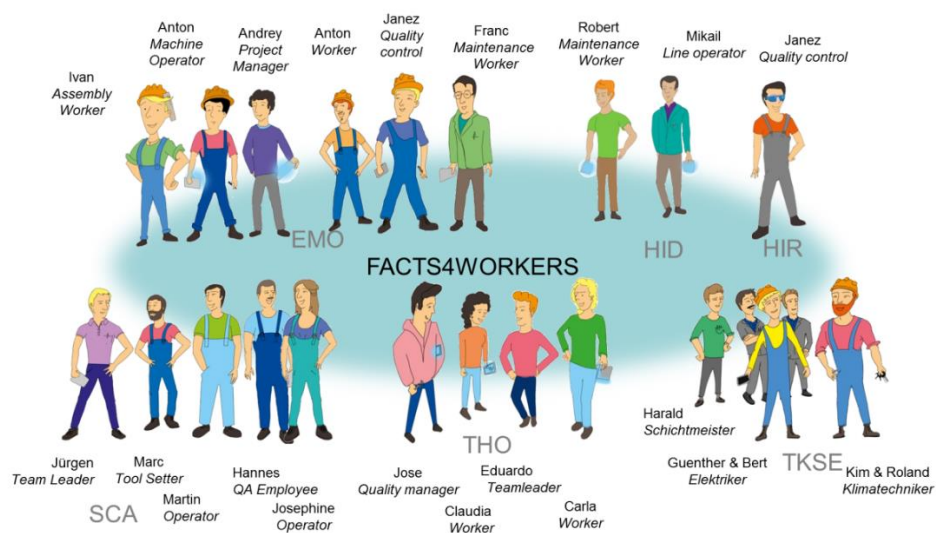
Figure 2: FACTS4WORKERS personas at the industrial partners

WP1 also developed a framework with seven impact dimensions and took a closer look at each of this context-of-use as well as at the intended impacts on individuals (autonomy, variety, competence, relatedness, protection) and organizations (quality,

time efficiency) which is the basis for a quantitative evaluation (see WP6) of the project objectives on work satisfaction and innovation skills increase.

Digital work Design approach

A specific requirements process was developed in FACTS4WORKERS with an iterative and agile approach and focus on the workers needs and acceptance. A description of this process and a first version of requirements of workers and organisations are in **Deliverable 1.2: First version of requirements of workers and organisations**.
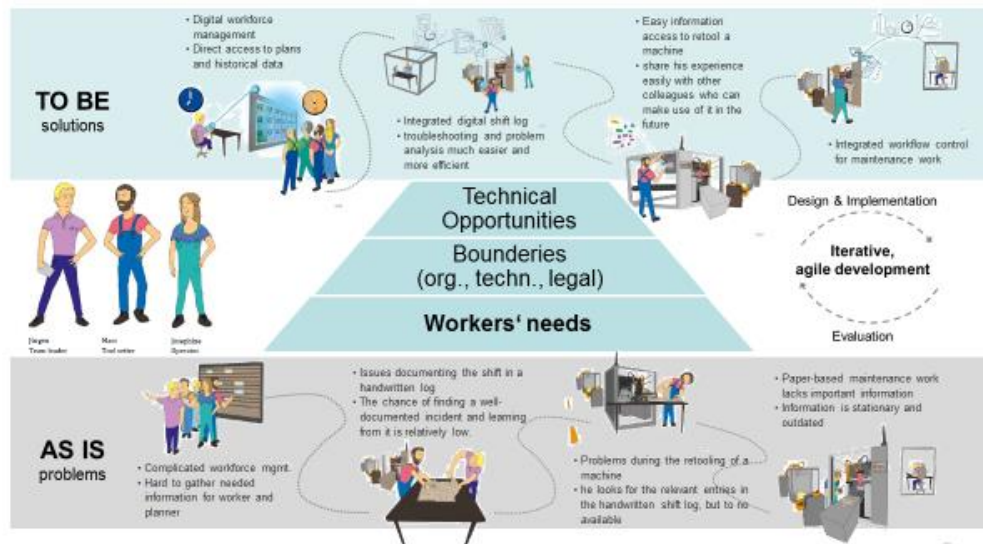
Figure 3: From workers to requirements

The **Deliverable 1.3 - Detailed and refined industrial challenges, version I** introduces the key production models in general and the related methods that manufacturing companies are applying. It reports on four Industrial Challenges (Figure 1) chosen from Industrial Partners of FACTS4WORKERS, which are also generalizable to other companies in the manufacturing industry. This four industrial challenges are updated and refined in the **Deliverables 1.4-6: Detailed and refined industrial challenges, version II-IV (confidential)**.

Development of prototypes

The development and refinement of prototypes included the iterative development of mockups and demonstrators to facilitate a deeper understanding of the requirements. Regular contact with the workers helped to focus on their needs as a core consideration and to deeply involve them in the development.

Further support of Use Cases

After the hand-over of all Use Cases from UZH to specific Use Case responsibles at other organisations, WP1 focused on the further support of the knowledge transfer.

To ensure the quality of the knowledge transfer WP 1 drives needed action based on an interview study with all Use Case leaders in March 2017. The main objective was to develop strategies to support the Use Case responsibles during the rollout of the prototypes and ensure that the focus stays on the worker's needs.

Focus on exploitation of the developed Digital Work Design approach

Besides the ongoing project related work, the WP 1 team focuses on the exploitation of the Digital Work Design approach. Main goal here was to make this approach accessible to academia and practice.

Foundation

- **DWD supports heterogeneous project teams**

  The DWD approach was developed and is validated in a heterogeneous project team. The heterogeneity has assorted characteristics
  - Company size: large, medium-sized, small cooperation
  - Project members across 6 European countries with different cultural backgrounds and native languages
  - Very different educational backgrounds and disciplines: Production (worker till manager); scientific (undergraduate assistant till full professors)
  - Various stakeholder: unskilled worker, skilled worker, production manager, manager, directors
  - Large scale project: 1.081 person months over 4 years

- **DWD enables agile development in industrial context with the focus of the workers**

  The DWD approach offers several artefacts for different phases of the agile development of a worker centric solution
  - for As-Is: BPMn as is; Problem Scenarios
  - for transformation: Persona; Used information
  - for To-Be: BPMn should be; Activity scenarios; Building blocks; Prototypes

Key learnings

- **Communications first**
  - When the communication to the workers is stable, the motivation is stable too

- **Small viable & useable software increments**
  - DWD supports worker centric and agile projects in industry context

- **Comics & prototypes matters**
  - A comic may be worth a thousand lines of requirement specification
  - A prototype may be worth a hundreds comics

Figure 4: Digital Work Design approach and key learnings

First, we validated trough one-to-one conversations together with the other work package leaders the foundations of the DWD approach and the key learnings of applying it.

Based on those results and the driven scientific work we developed easy understandable text material and graphics for industry responsible. For example on our exploitation website i40cases you can find one example (in German): http://i40cases.com/neuigkeiten/methoden-des-digital-work-design/.
Another example which is used in presentations to industry representatives is Figure 5, which shows Digital Work Design for worker centric digital solutions in the context of industrial processes.

Figure 5: Digital Work Design for worker centric digital solutions

1.2.2   Work package 2 - Worker-Centric HCI/HMI Building Blocks

The focus of WP2-Frontend Technologies and Infrastructure within the FACTS4WORKERS project was on the investigation, development and dissemination of the interfaces that allow workers on the shop floor to make best use of the provided assistance systems. Therefore, the work in WP2 can be generally seen from two perspectives: the hardware and the software part.

Hardware

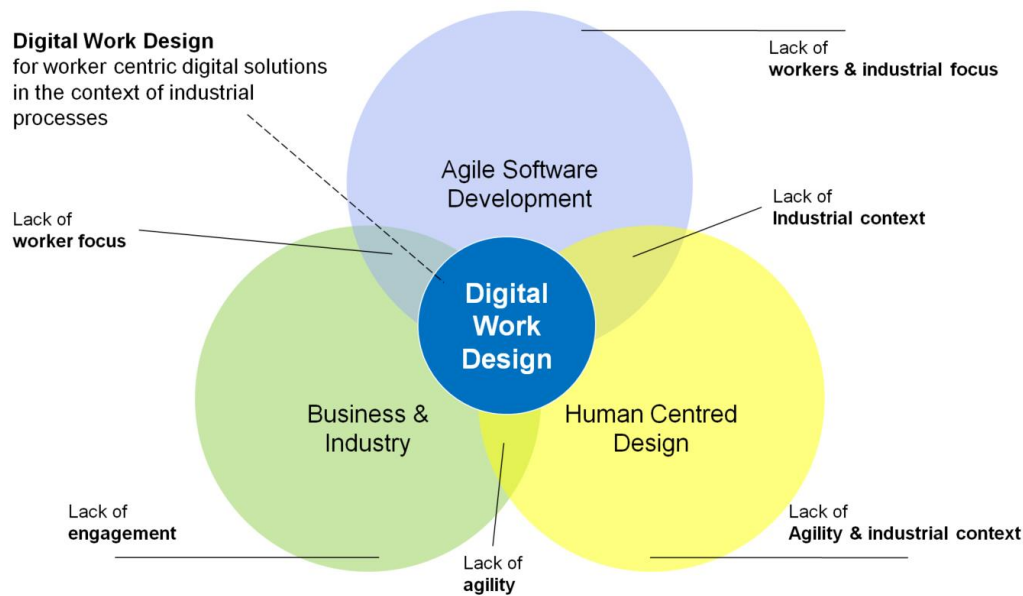In this context hardware are the physical devices that the worker uses in order to access information and knowledge through the assistance system. Typically, devices such as tablets or smartphones are used in this case; for some situations however, wearable devices like smart glasses or smart watches provide significant advantages since the worker still has his hands free for the physical task while he is able to access digital information simultaneously. Since there exist a whole range of devices for each of the before mentioned categories (tablets, smartphones, smart glasses, smart watches), the careful choice of the appropriate device is important. However, in Facts4Workers the focus was not on choosing a hardware device and then developing software applications that fit the devices. Our approach was to design applications that best fit the requirements of the workers and select the correct hardware that supports these requirements accordingly. Since the update cycles in the area of mobile and wearable devices are relatively short (1 – 2 years typically) we prepared for

exchanging and updating the hardware during the project's lifespan already from the beginning.

Figure 6: Hardware devices

In order to support well-grounded decisions when choosing the appropriate hardware devices and support planning for upcoming new devices, we conducted a market research on a yearly base. This research included an overview of available state-of-the-art hardware as well as trends in this area that should be considered. Furthermore, a taxonomy was created that evaluates the industrial suitability of each device – this helps with early decisions about which category of device might be suitable for a use case. Since the market for mobile and wearable devices is vivid, we published the results every year in order to stay up to date. The results can be found in the **deliverables 2.1 – 2.4: Technology Monitoring: Report on Information Needed For Workers in the Smart Factory**.

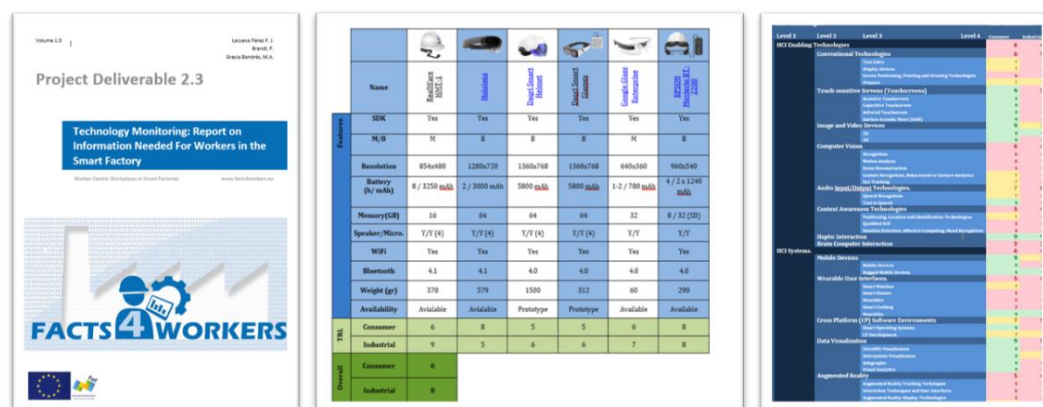**Figure 7: Technology monitoring deliverables**

Software

As mentioned before, short update cycles in the hardware sector had an impact on the selection of the appropriate devices. Moreover, this fact of course had a considerable impact on the software development, too. The design of the applications and all underlying technical considerations had to be flexible enough to work for different

hardware devices without the need of major adaptions. Therefore, we decided in an early phase of the project to switch from native application development (e.g. Android and iOS applications that only work on the supported hardware) to a more general approach. Based on Angular, a JavaScript-based open-source front-end web application framework, we were able to develop applications that can be used across platforms. This means we support the maximum range of different hardware devices and thus can deal with changing hardware quite easily. While Angular was in an early beta phase at the beginning of the Facts4Workers project, it meanwhile developed to a standard that is commonly used for state-of-the-art software development. An overview of the developed applications can be found in **Deliverable 2.6: Final worker centric HCI/HMI building blocks (confidential)**. Written from a use case perspective, in this deliverable we report our results in a way that similar projects and potential industry customers can carry over our outcome.
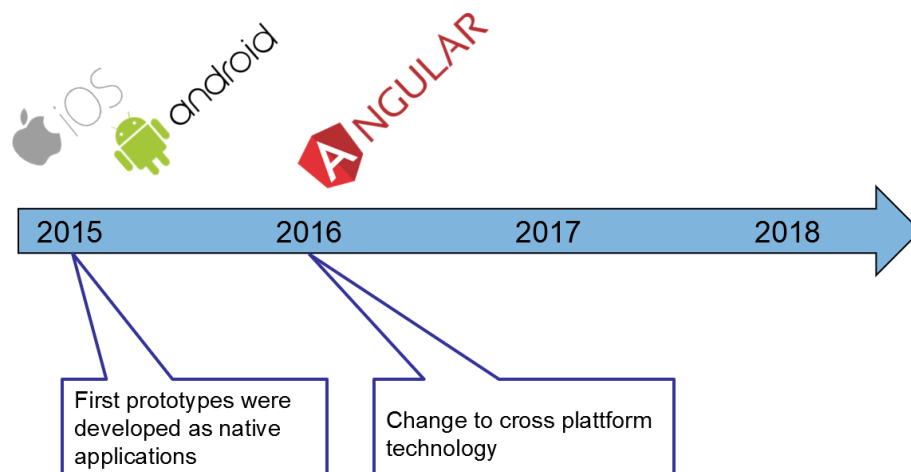
Figure 8: Frontend software technology

While the hardware devices are changing in short timespans and software development frameworks experience frequent updates and improvements, we decided to develop design guidelines that are more general applicable for industry use cases independently from the underlaying hardware or the selected programming framework. These guidelines were meant to be general enough to be applied outside of the scope of FACTS4WORKERS but at the same time deal as a base reference for our own implementations. The result is reported in **Deliverable 2.5: HCI/HMI building blocks: Report on guidelines for intelligent information presentation to the workers (confidential)** in form of 19 design guidelines with various examples for practical use on tablets, smartphones, smartwatches and smart glasses.

Based on the Software and Hardware strategy agreed within the consortium, all front ends of the 8 use-cases have been implemented. To validate the Soft- and Hardware approaches, all industry relevant and required front end technologies have been

demonstrated, such as MS-Hololens, smart glasses, mobile phones or tablets on various operating systems.

1.2.3   Work package 3 - Worker-Centric Service Building Blocks

In close cooperation with WP2 and WP1, WP3 has provided a preliminary definition of each context-of-use in terms of information requested by the workers to support their empowerment and a technical concept needed to provide such information and reported it in **Deliverable 3.1: Report on data, information and technology needs (confidential)**. WP3 has also provided a first set of specifications for the development of the service building blocks and developed preliminary workflow descriptions for the contexts-of-use for the industrial cases. WP3 has also defined detailed definition of the input and output expected from the building blocks and the technical concept to be used for each. For some contexts-of-use a scheme of the workflow of the building blocks has been provided. Detailed descriptions can be found in the following deliverables:

- **Deliverable 3.2: Semantic search service (confidential)** reports initially the possible applications of a semantic search service.
- **Deliverable 3.3: Integration of social feeding service (confidential)** reports initially the possible use cases and application of a social feeding service.
- **Deliverable 3.4: Pattern extraction service (confidential)** reports initially the possible applications of pattern extraction services.

Based on this preparatory work WP3 developed the service building blocks and the interface with the HMI and infrastructure, developed respectfully within WP2 and WP4 (Figure 9). A description and all the basic data of all the building blocks are provided in:

- **Deliverable 3.5: Final worker centric service building blocks (confidential)**.

A preliminary activity has been carried out to select the optimal deployment strategy and the approach to coordinate the programming efforts. At the end, Docker technology has been selected to assure a simple and smooth installation of the service at the IPs' premises. As soon as a building block has arrived a usable stage, it has been included in a Docker container and its image uploaded on a sharing platform. This has enabled a fast diffusion of the developed software among the partners and the possibility to debug and include additional functionalities as soon as possible.
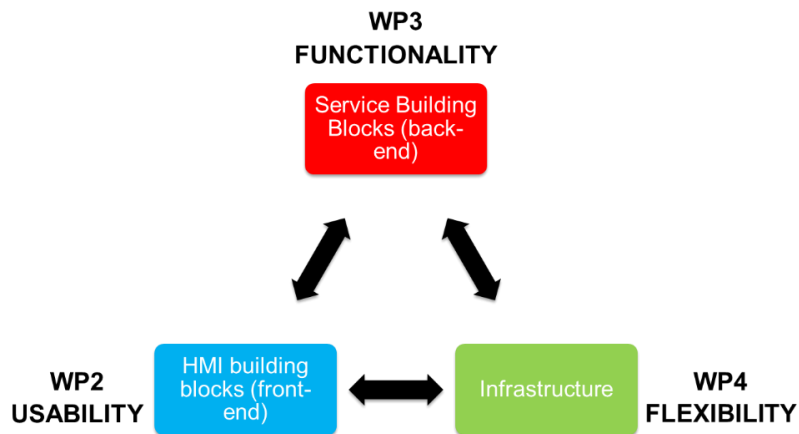
Figure 9: Components of FACTS4WORKERS solution

The first release of FACTS4WORKERS solution deployed at the Industrial Partners sites in the third year of the project has been deeply tested by the workers. The feedback provided to the developing partners has been used to refine the functionalities of both backend and frontend blocks. The main tasks carried out in WP3 for last period of the project have been focused on the final review of this already released building blocks and the introduction of new ones to complete the functionality required by the solution released at the use case test sites. For backend blocks, based on the evaluation results conducted by WP6, many modules have been reengineered in order to provide a better usability and user experience beside the defined functionality.

Figure 10: Used technology independent platforms

Based on the feedback of the workers, sometimes has been required to introduce new functionalities to the developed solutions and this required the development of new blocks. Since in the last phase of the project the objective has been to look for a better integration of the solution with the existing ICT infrastructure of the Industrial Partners, some connectors have been put in place to increase the communication among these two infrastructures.
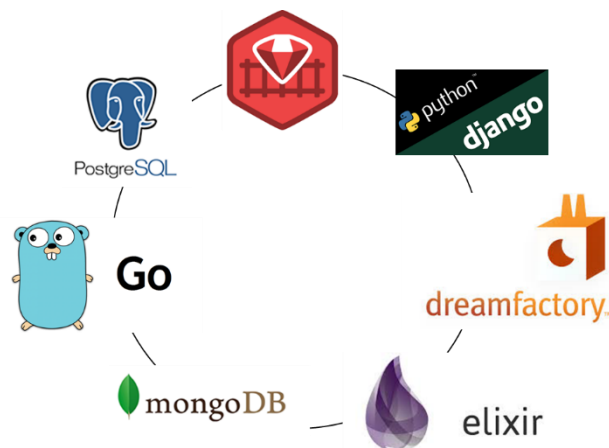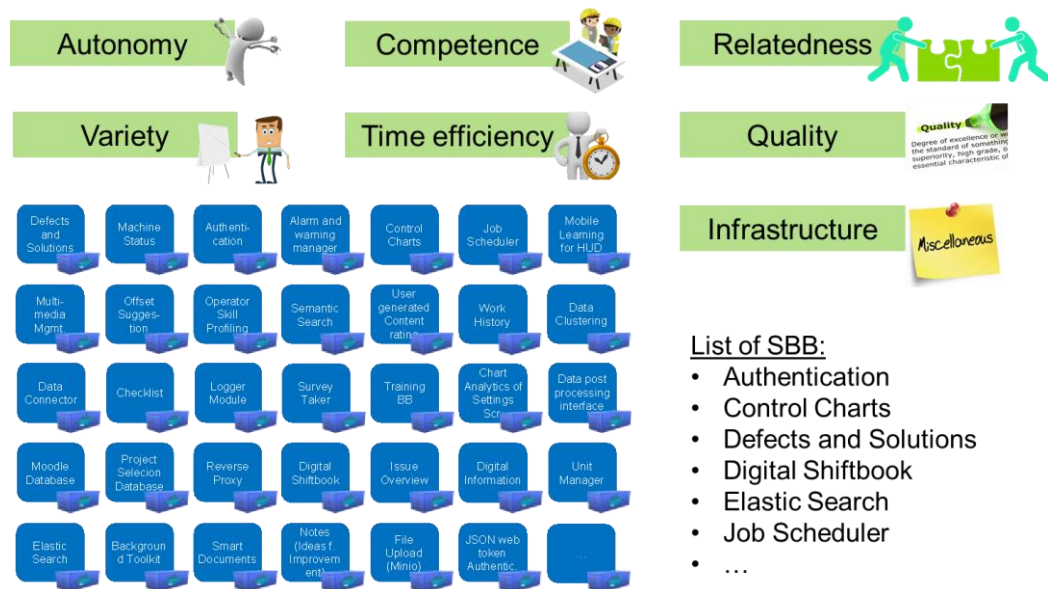

Figure 11: FACTS4WORKERS Service Building Blocks

In the last phase of the project, we cross reviewed the developed backend blocks with the objective to understand the problems that an external software engineer – from outside the project – would face to use the developed blocks. It is important to remind that all the blocks have been released under open source license and could be adopted by any interested user after the end of the project. This led to the complete review of the documentation of the building blocks, that now has been developed till a detail level that allow an easy and fast introduction of the developed blocks functionalities inside a complete software solution. The data structure of the building blocks, its functionalities and REST calls have been included in the documentation.

The last step of WP3 activities has been the development of the material required for FACTS4WORKERS on-line free marketplace. This included the development of the final version of the docker container for each building blocks, its documentation and a description of its application within an industrial case, highlighting the advantages for the blue collar workers and how it has been applied in the flow of activities of an industrial company.

1.2.4   Work package 4 - Smart Factory Infrastructure

WP 4 covers the general architecture of the project and how different work packages are linked together.

There were several issues that the architecture solution had to solve:

- Independence: there are several different development groups in the FACTS4WORKERS project. A solution was required where each team could work independently on their solution without having to require the other teams all the time.
- Communication: this means the internal communication on the server infrastructure, how the system would be accessed and how the interaction would work with the already existing factory servers.
- Flexibility: there would be different kinds of servers and different kinds of interfaces. A flexible solution that could work on many systems was preferable so most work could be reused in between solutions.
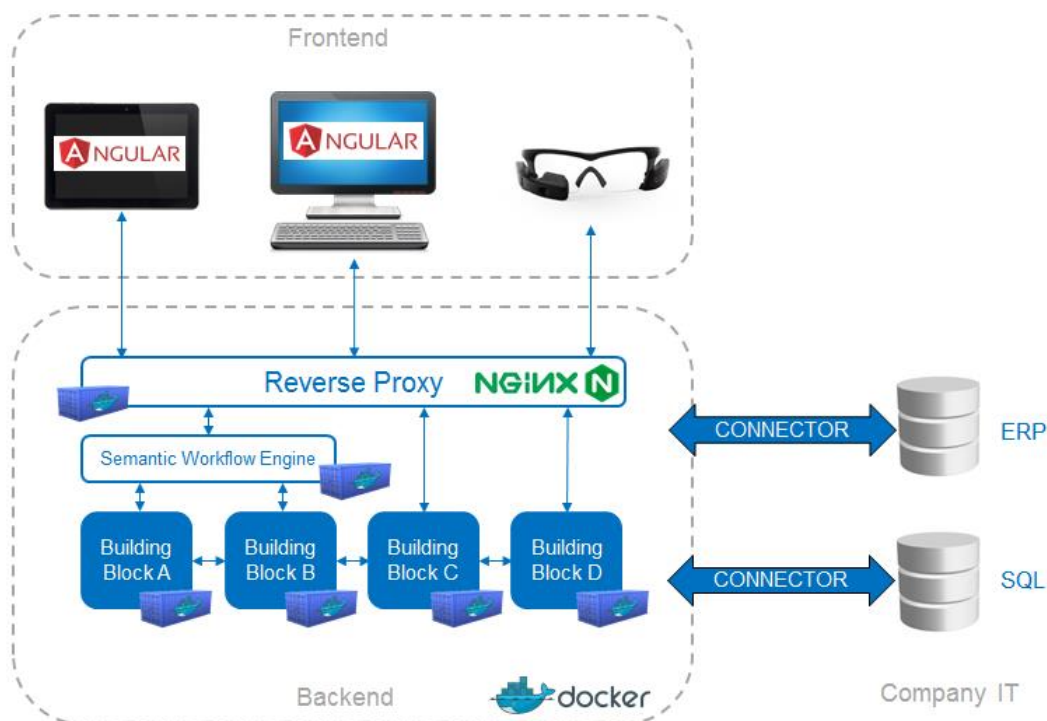

Figure 12: FACTS4WORKERS system architecture

The solution decided on was a modular composition of building blocks, all developed independently and then linked together in one big solution. These blocks would then all focus on solving a singular problem on their own, and solutions that required combinations of these problems could then link these blocks together in a single server.

Docker

For the building block solution Docker was used, which was an upcoming technology when the project started. Meanwhile this has been adopted by many big companies and is now the de facto standard for micro service architectures. FACTS4WORKERS allowed everyone in the project to acquire valuable experience with creating and setting up such architecture, which can be quite useful in the future.

HTTP

The communication between all components was solved by using RESTful HTTP APIs. This is a standard from the Web and allows for easy independent communication, making use of a large collection of libraries that exist for HTTP. Additionally, a reverse proxy is used when the frontend is communicating to allow hiding the backend internals and to provide caching.

Angular

Finally, to allow for flexibility in the frontend so different devices could be supported, HTML5 stack was used. Due to the nature of how HTML, CSS and JavaScript interact, only minor changes would be required to adapt the solutions for different devices. The Angular framework was used to tie these all together.

Semantic Workflow Engine

One specific component that was designed in WP4 is the Semantic Workflow Engine (SWE). This is a system that dynamically generates workflows, based on the output required, and changes it on the fly while the system is running based on API responsiveness and results. This means that different paths get chosen if required, based on the user input as well. This requires all the available APIs to be annotated with SWE metadata so the engine can interpret them. Especially for very flexible workflows when workers are in need to adapt processes, this approach has been validated, whereas for linear workflows the descriptive overhead is not required. In this case the process is controlled by the reverse proxy architecture directly.

Deliverables

- **D4.1: Functional Workflow Composer**. This deliverable is the SWE. The corresponding document fully describes the implementation and algorithm behind the engine.
- **D4.2: Functional Service Repository**. This is a repository containing all the building blocks created for the project.

1.2.5   Work package 5 - Deployment: Smart Factory Industrial Challenges

At the beginning of the project, WP5 investigated the deployment requirements and the available deployment technologies. The main challenges of the project were the high number of developers in different countries, the usage of different development languages and frameworks, and the diverse IT environments at the different industrial partners. To address these issues, a deployment strategy based on the container technology and micro services was chosen (see **D5.1**). In particular, "Docker" was identified as most comprehensive technology with respect to the requirements of FACTS4WORKERS.
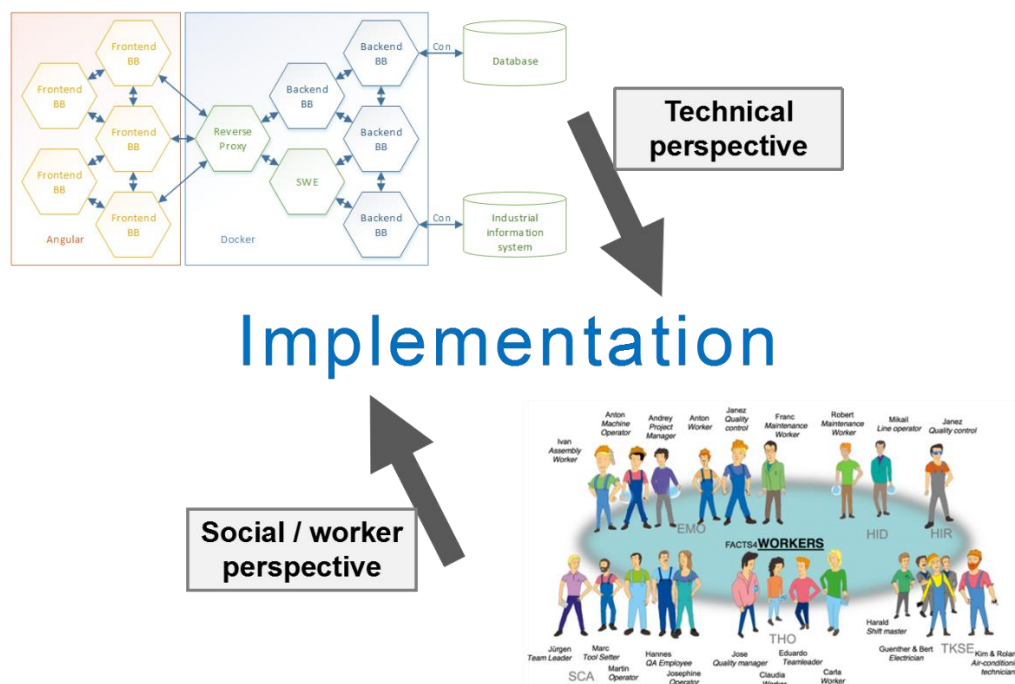
Figure 13: Implementation aspects

To ensure a successful implementation at the industrial partners, the required tasks were identified. The time necessary for completing each task was determined and the dependencies between them were identified. Further, an implementation plan was developed (see **D5.2**), which included the coordinated tasks, a timeline, and the responsible persons. The final review presentation (Figure 14) provides an overview over the different tasks.

- **Deployment preparations**
  - Tasks performed preliminary to the deployment

- **Deployment**
  - Tasks performed during the deployment

- **Follow-up work**
  - Tasks performed after the deployment
  - *Optional:*
    - Tasks performed in preparation for the next deployment
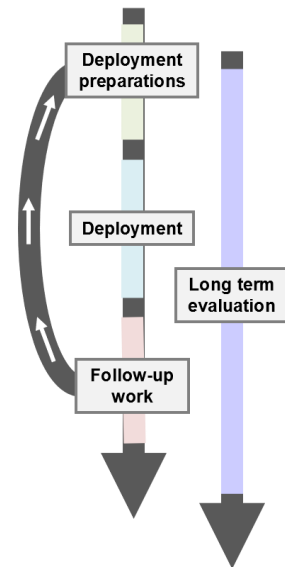
Figure 14: Social/worker perspective of implementation

An important aspect of WP5 dedicated high efforts to planning, development, and implementation of the connectors between the FACTS4WORKERS solution and the individual IT infrastructure (see **D5.3**). These connectors enable the exchange of data in different formats and are therefore fundamental to ensure the actuality of the data. In order to connect highly specific environments, a special focus was put on the development of flexible solutions that can adapt to changes easily. A detailed use case example for such a connector is given in the EMO use case presentation.

A strategy for the user training was elaborated in the run-up to the first deployments. The workers that were most interested in participating in the development of the solution were chosen to undergo an extensive training. Afterwards, these "super-users" trained the other workforce while using the FACTS4WORKERS solution during their regular tasks. Having a hands-on training from an experienced colleague reduced the reservations of the work force against the introduction of new technologies at the shop floor. Pursuing this approach was a key factor for the successful deployment.

Based on the previously described activities, the solution was deployed successfully at all project partners (see **D5.4** and **D5.5**). This included setting up the IT infrastructure, deploying the solution, and training the super users. As the deployment was performed stepwise, it was possible to transfer and apply knowledge gained at one partner to others.

Finally, WP5 elaborated possible advancement strategies for the time after the project end. As shown in the final review presentation, this includes the continued usage, further development, or migration. Depending on the industrial partner, use case, involved BB, and maturity of the BB, different advancement strategies are favorable.

To report on performed activities, the deliverables D5.1 to D5.5 as well as the Milestones 3, 10, and 13 were authored within WP5.

- **Deliverable 5.1: Blueprint architecture and integration plan** summarizes the approach FACTS4WORKERS has taken to develop, deploy, integrate, and test the worker centric software solution. This concept allows to introduce the solution in several steps and constantly gather feedback from workers.

- **Deliverable 5.2: Implementation plan** states the activities performed as part of the implementation and deployment process. The plan includes the tasks required for gathering the needed information, defining the deployment plan, and aligning the individual deployment strategies.

- **Deliverable 5.3: Interface and adapter specification** (Confidential) provides an intermediate overview over the APIs of the building blocks and connectors of the FACTS4WORKERS solution. The objective is to facilitate external programmers (and all persons interested) to develop own building blocks and integrate them into the FACTS4WORKS system.

- **Deliverable 5.4: Implemented and tested interfaces** (Confidential) consists of two parts. First a framework for categorizing the exchanged data is presented. Afterwards, the different use cases are presented starting with a textual description of the interfaces and their interaction with the IT solution of the company. Thereby, the exchanged data is analyzed more in detail using the presented framework.

- **Deliverable 5.5: Deployed smart factory solutions** (Confidential) reviews the deployed smart factory solutions, starting with an overview over the possible advancement strategies for the developed BB. This also includes a listing of the IP-specific courses of action. Further, the developed solutions are discussed based on the worker-centric system development approach pursued by FACTS4WORKERS.

- Milestone 3 presents the implementation and deployment approach followed by FACTS4WORKERS. Pursuing an agile approach, the architecture is determined, and the different development states are defined.

- Milestone 10 presents the evaluation results conducted on the first FACTS4WORKERS solution prototype. For each IP, the evaluation set up, the results, and the impact on the workers and organizations are discussed.

- Milestone 13 presents the final evaluation results of the FACTS4WORKERS solution. Again, the evaluation set up, the results, and the impact on the workers and organizations are discussed for each IP.

1.2.6   Work package 6 - Demonstration & Evaluation of Smart Factory Solution

During the first half of the project duration the main tasks of WP6 have been the ones focused to the development of the FACTS4WORKERS Evaluation Framework, which is described in **Deliverable 6.1: Evaluation framework**.

The bricks used for building the Evaluation framework have been both the initial works and indicators developed in WP6 during first project year and the achievements of WP1, specially the worker impact dimensions detailed in 1.2.1.
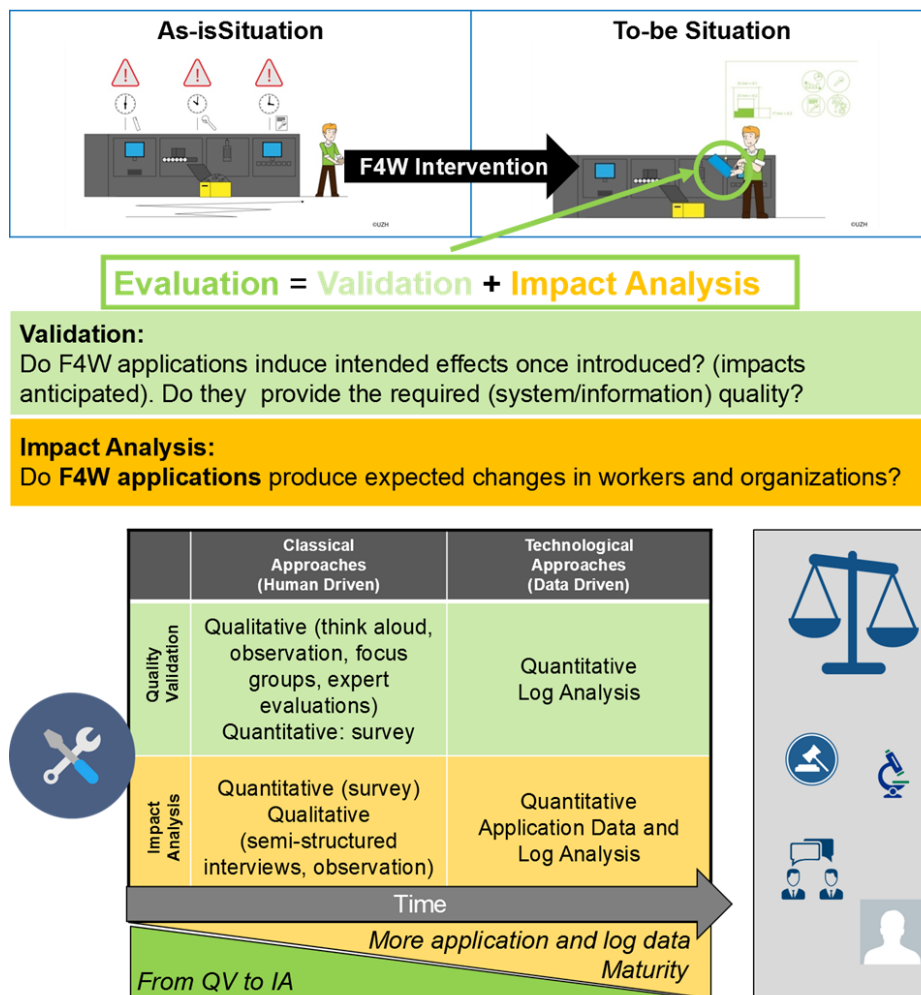
Figure 15: Evaluation framework overview

After the development of the evaluation framework WP6 focused on the definition of the strategy (see **D6.2 below**)for using it for assessing the impact of interventions introduced in the deliverable. To define the strategy, a practical approach has been followed. In the first place, a generic deployment framework was defined to, secondly, correct the errors detected in the tools provided by the framework and/or in the deployment strategy itself. In this way it was possible to generate results that feed back

into the project development packages (WP1-5) and, in addition, improve the tools provided with the framework as well as the deployment strategy itself.

During the second half of project duration WP6 focused on the improvement of the framework, the execution of the evaluations and the creation of the reports, ICs challenges and UCs driven which support the extraction of the general conclusions of project and of the evaluation framework itself. Moreover, we disseminate our work, FACTS4WORKERS evaluation framework, by presenting it and obtained results on several conferences and journals.

The work started after the first execution of the evaluations in the different IPs. Based on the observations of the evaluators and on the feedback from workers the tools presented to the workers were improved in order to make them better understandable by workers by including clear explanations about the project goals, use case goals and evaluations goals which, in the last case, also include clear definitions of the evaluated concepts. The questionnaires were also modified for making questions simpler a clearer but maintaining their meaning.

The implemented modifications were taken in account in the definition of the evaluation strategy, the quantification processes and the interpretation of the obtained results which were defined in **Deliverable 6.2: Evalution environment defintion and setup (confidential)** . It explains how to select and use the tools best fits to each UC environment in order to obtain valuable results from the evaluation processes as well as, to preserver workers' rights.

This deliverable was used as base for performing the evaluations of the second releases of prototypes during the second half of 2018 as they were deployed in IPs. The obtained results were used for creating D6.3 and D6.4 project reports and for feeding back development teams (that is WP2-5) in order to solve problems detected during the deployment of prototypes or their user.
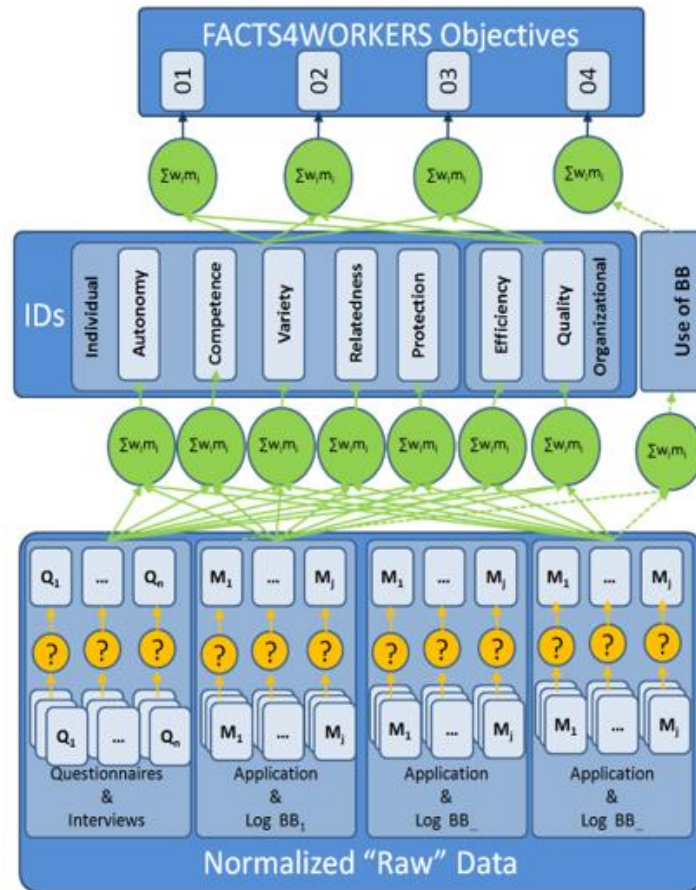
Figure 16: From raw data to project objectives

Deliverables 6.3: Industrial Challenges specific evaluation reports, which was created during the evaluation process, analyses the results obtained from the IC perspective. As it was shown in deliverable, FACTS4WORKERS prototypes contribute to improve the workers cognitive job satisfaction, problem solving and innovation skills and, productivity of workers using them. Reported UCs, which are ICs "leaders", in consequence advanced on achieving ICs goals.

Deliverable 6.4: Final evaluation report reports the obtained results from the UCs, generalizes them to the project level and shows the conclusions obtained from the use of the framework. Our purpose is to highlight the learned lessons to be considered both for using FACTS4WORKERS Building Blocks in the future or by other Industry 4.0 projects considering different initial solutions of from scratch. While several valuable conclusions are included in deliverable D6.4, the most important is that workers, as experts on their tasks, provide high quality insights that can be used for detecting improvement opportunities not only for the solutions but also about their practices.

As part of the evaluation processes, the results of each evaluation were used by WP1 team in order to refine the requirements of each industrial challenge.
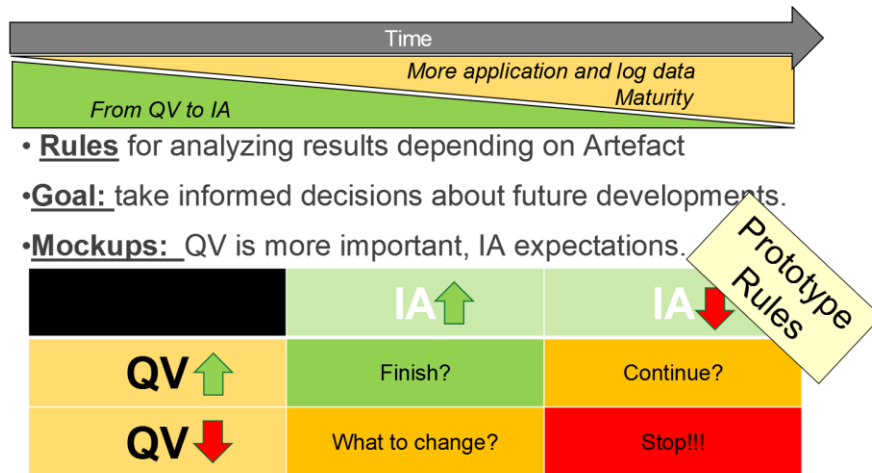
Figure 17: Data interpretation

Considering that the framework was tested for evaluating 8 different UCs at 6 different IPs under different legal restrictions with different maturity level artefacts, it shows its flexibility and capacity of obtaining results. It has been submitted to the community interest by presenting on different conferences and it is being used and exploited by the Big Idea consultancy services of ITAINNOVA.

1.2.7   Work package 7 – Impact: Dissemination and Future Exploitation

After defining a corporate identity of the project for external communication and dissemination activities, WP7 conducted an analysis about the dissemination and exploitation achievements. WP7 leader SiEVA Research Centre (SIA) and the Virtual Vehicle Research Center (VIF) thoroughly revised the main dissemination process and the main document in the process creating a new **Deliverable 7.2: Dissemination and Exploitation Plan**.

Figure 18: Project website

In area of project dissemination, special focus was given to the outreach to the scientific and academic community with publications in peer-reviewed journals and conference papers, project presentations at conferences, trade shows and exhibitions, and participations at workshops. Other dissemination activities included our **project website** **(corresponds to Deliverable 7.1),** appearances at mass and social media, a **project video on YouTube** and various dissemination materials (brochure, poster, …). In addition, the project received TV airing time on the television, the members engaged in project networking processes with SATISFACTORY project and the solutions of the project were represented on an additional **i40 cases website**.
The **Deliverables 7.3 – 6: Activities report (1) – (4)** present all dissemination and exploitation activities carried out in every of the four project years.

Figure 19: Dissemination materials

After a strong focus on dissemination at the beginning, the project was then focused on exploitation activities to ensure a wide deployment and usage of the developed

solutions. The project's exploitation effort builds upon the strategy that is set up in **Deliverable 7.7: Business plan (confidential)**. The project consortium defined clear exploitation pillars to be used in the process (see **D7.6 above** for details):

1. consultancy services
2. products and services
3. induced other research activities

Industrial partners used the FACTS4WORKERS project for further internal, bilateral or European project activities and initiatives. Scientific partners within the project also exploited the results via new services and projects -as was already visible in the project's third year – greatly surpassed the project plan in field of scientific dissemination as outlined in the project' application.
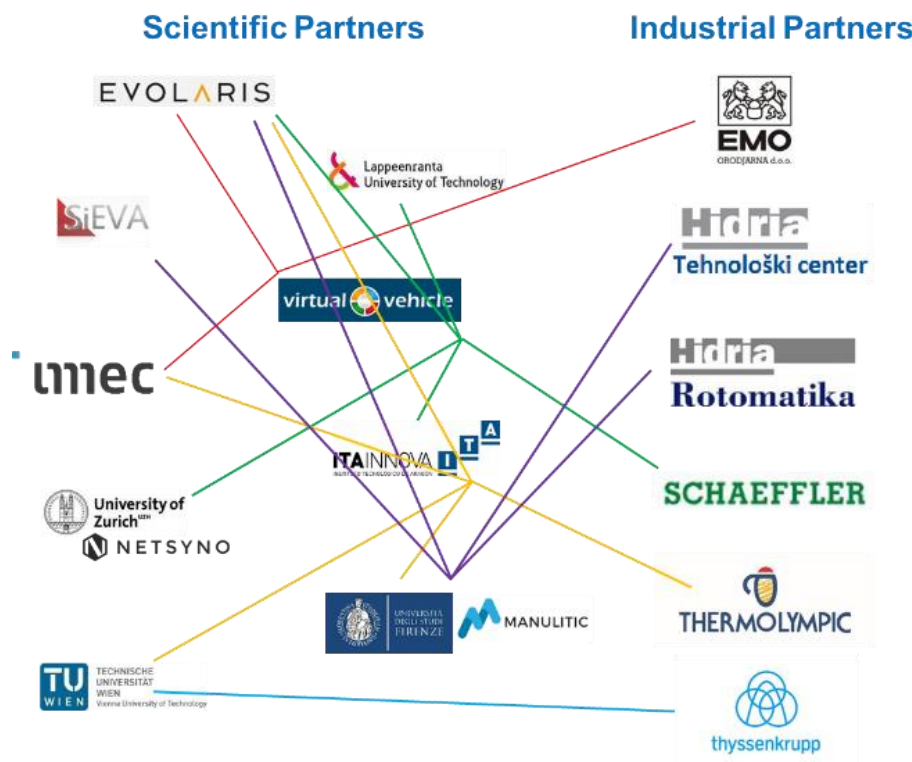
Figure 20: Future collaborations

The consortium managed to lead this 4-year project in an organized way, step-by-step. From first dissemination plans, brainstorming activities on the consortium level regarding exploitation, developed business plan and the final FACTS4WORKERS' solution roll-out at the industrial partners with a clear interest to continue research activities after the project's end, the project has grown and developed as the work progressed. Taking into account the rapidly developing and maturing IT technologies that were used in the project, the consortium managed to form relevant solutions for all the stakeholders proving the usability and adoptability of the UC-related solutions in a wider industrial field.

In WP7 all partners were involved but the main work and responsibility was a close collaboration between the two responsible partners SIA and VIF. The two partners closely supported each other and provided help when and where needed. Communication was always open and strategically included industrial and scientific partners if necessary. The distribution of efforts per partners has been also proven as very realistically planned.

To give a final update about FACTS4WORKERS dissemination and exploitation efforts: During the four years the project was very well presented at different events, provided 35 scientific publications, participated or organized workshops, prepared press releases and realized a large number of other publications. To boost dissemination activities, we use social media tools, including - blogpost (Tumbler, website), Facebook, Twitter, LinkedIn and YouTube. Figure 21 shows a clear summary of the dissemination results archived.
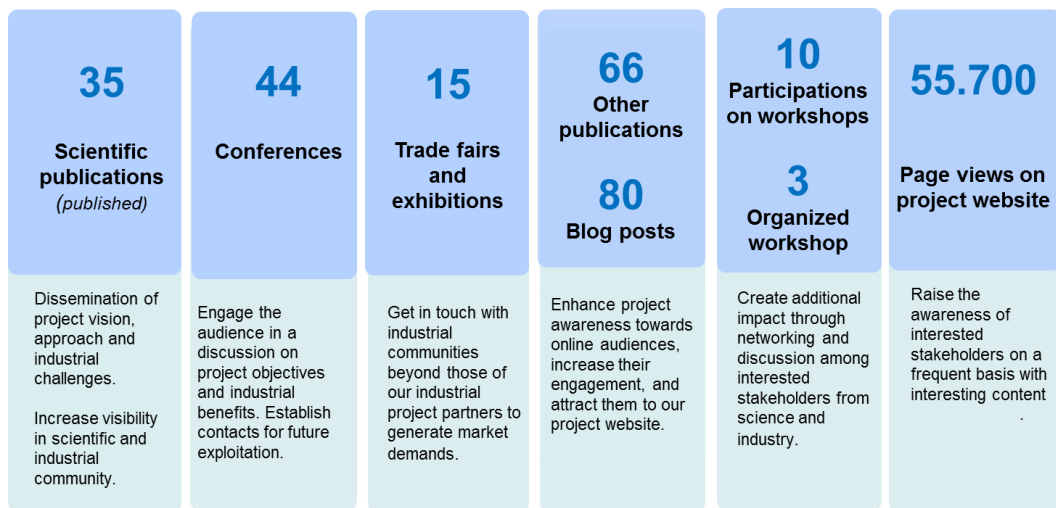
Figure 21: Summary of archived dissemination results

At the project's end, the FACTS4WORKERS consortium achieved its goal in developing a wide array of useful solutions that would have as large scope of implementability as possible and would be beneficial for multiple branches of European industry in the 21st century.

1.2.8 Work package 8 – Project Coordination

The project coordination conducted by Virtual Vehicle has been successful. All partners have expressed during the Lessons Learned workshop their satisfaction with the operational and financial management of the project. The coordinator Mr. Martin Wifling has been managing the project throughout the whole project, from the proposal phase, throughout the project preparation and the whole project lifetime until

the project closing phase maintaining continuity and the general idea of the project.**General Assembly meetings**

As defined in the Annex 1 and in the general rules to manage H2020 projects, every 6 months there has been a F2F meeting of all project partners at various project sites. At this meetings, important project decisions such as budget relevant issues, project timelines and priorities, use of resources etc. have been taken. All General Assembly meetings have been documented by meeting minutes.

Meetings	Date	Venue
1st GA meeting (kick-off)	13.01.2015	ViF, Graz, Austria
2nd GA meeting	15.02.2016	EC, Brussels, Belgium
3rd GA meeting	02.06.2016	ViF, Graz, Austria
4th GA meeting	14.02.2017	SCA, Ingolstadt, Germany
5th GA meeting	21.06.2017	HID, Spodnja Idria, Slovenia
6th GA meeting	01.02.2018	ITA, Zaragoza, Spain
7th GA meeting	05.07.2018	tkSE, Duisburg, Germany
8th GA meeting (closing event)	20.11.2018	ViF, Graz, Austria

Figure 22: General Assembly meetings

Executive Board meetings

To maintain the operational management of the project, a technical and organisational meeting, the "Executive Board Meeting" was held on every 2nd Tuesday per month, mostly as a virtual meeting utilizing webex. All project partners have been required to attend the Executive Board meeting, either the General assembly representatives or any substitutes. The Executive Board meeting has been conducted 47 times, the minutes have been rolling online minutes in order to have all issues tracked until the consortium has agreed to have them solved.

Furthermore, a Software Developers Jour Fixe (to cross-link software developers) and a Use-Case meeting (to track the progress of the individual Use-Cases) have been conducted alternating on every Friday on a weekly basis.

Review meetings

According to the rules on H2020 projects, FACTS4WORKERS has been assessed after 12, 30 and 48 months of the project duration. All assessments have been passed with positive feedback from the reviewers (Prof. Paul Xirouchakis and the respective Project Officers).

Month	Meetings	Date	Venue	Focus
M12	1st Review meeting	16.02.2016	Brussels, Belgium	12M review
M30	2nd Review meeting	22.06.2017	Tolmin, Slovenia	30M, Mid-Term review
M48	3rd Review meeting	08.11.2018	Brussels, Belgium	M48 Final review

Figure 23: Review meetings

At the end of the project duration the final-review meeting was held in Brussels on 8th of November 2018. This meeting was prepared with great emphasis and mastered, generally receiving very positive feedback.

Within the public closing meeting on 22nd of November 2018, there has been also an evaluation of the innovation radar by Mrs. Gabriele Jansen, with very positive feedback. However, due to the nature of the project with the main focus on utilizing existing technologies from consumer or other domains for the manufacturing domain and the explicitly defined target to provide all solutions via open source to the public, innovations have not been in the main focus. Nevertheless, economically successful business cases (see WP7 exploitation chapter) could have been established which was well received during this evaluation.

An internal Lessons Learned workshop also has been conducted during the last General Assembly meeting which gave valuable feedback to all project partners.

Advisory Board

In contrary to the usual practice to nominate members of an advisory board, the FACTS4WORKERS consortium has decided to collaborate with experts from adjacent domains which are not covered by the consortium members directly but are of high interest to make the project successful. The members have been chosen mainly to cover important target groups (workers unions), interest platforms and policy makers (Plattform Industrie 4.0), legal advice (law group specialized in Industry 4.0 domain) and for cooperation purposes ("sister" project in same FoF cluster). The members of the Advisory Board have been contacted whenever relevant decisions had to be taken. The Advisory Board has provided their best and honest opinions and expertise in exchange for insights in the actual developments and findings of the project. The collaboration with the Austrian Production Workers Union (PRO-GE) has to be highlighted. The findings of FACTS4WORKERS are transferred into best practice advises given to any interested party approaching either PRO-GE or the platform Industry 4.0 in Austria on how to implement such technologies.

Members of the Advisory Board:

- Austrian Production Workers Union (PRO-GE)
  Kerstin M. Repolusk, MA

https://www.proge.at/cms/P01/P01_5.4.11/ueber-uns/partner-koopera-tionen/industrie-4-0

- Legal Issues in Industry 4.0 domains
  Prof. Dr. Thomas Klindt
  Noerr LLP Law Firm, Munich

- Industry 4.0 policy makers:
  DI Roland Sommer, MBA
  Managing Director of Platform Industry 4.0 Austria
  http://plattformindustrie40.at/uber-den-verein/?lang=en#geschaeftsstelle

- H2020 cooperation projects
  Dr. Dimosthenis Ioannidis
  Coordinator of H2020 project SATISFACTORY

To assure confidentiality, an NDA has been signed with the members of the Advisory Board. A role description which defines the objectives, conditions and responsibilities is available.

Deliverables

All project results have been documented in project deliverables as stated in the Annex 1. The public deliverables have been made available to the public by publishing the on the project website without any download restrictions. The confidential deliverables are available to the reviewers and the consortium members only.

Deliverable Number	Deliverable Title	WP number	Lead beneficiary	Type	Diss. Level	Due Date (in months)
D 1.1	Captured and structured practices of workers and contexts of organisations	WP1	8 - UZH	Report	Public	9
D 1.2	Requirements of workers and organisations	WP1	8 - UZH	Report	Public	12
D 1.3	Detailed and Refined Industrial Challenges I, II, III and IV (1)	WP1	8 - UZH	Report	Public	12
D 1.4	Detailed and Refined Industrial Challenges I, II, III and IV (2)	WP1	8 - UZH	Report	CO	24
D 1.5	Detailed and Refined Industrial Challenges I, II, III and IV (3)	WP1	8 - UZH	Report	CO	36
D 1.6	Detailed and Refind Industrial Challenges I, II, III and IV (4)	WP1	8 - UZH	Report	CO	48
D 2.1	Technology Monitoring (1)	WP2	11 - EVO	Report	Public	12
D 2.2	Technology Monitoring (2)	WP2	11 - EVO	Report	Public	24
D 2.3	Technology Monitoring (3)	WP2	11 - EVO	Report	Public	36

D 2.4	Technology Monitoring (4)	WP2	11 - EVO	Report	Public	48
D 2.5	HCI/HMI Building Blocks	WP2	11 - EVO	De-monst-rator	CO	16
D 2.6	Final worker centric HCI/HMI building blocks	WP2	11 - EVO	De-monst-rator	CO	42
D 3.1	Report on data, information and tech-nology needs	WP3	3 - UFI	Report	CO	9
D 3.2	Semantic search service	WP3	3 - UFI	Other	CO	20
D 3.3	Integration of social feeding service	WP3	3 - UFI	Other	CO	24
D 3.4	Pattern extraction service	WP3	3 - UFI	Other	CO	28
D 3.5	Final worker centric service building blocks	WP3	3 - UFI	Other	CO	42
D 4.1	Functional workflow composer	WP4	6 - IMI	Other	Public	24
D 4.2	Functional service repository	WP4	6 - IMI	Other	Public	42
D 5.1	Blueprint architecture	WP5	4 - VUT	Report	Public	20
D 5.2	Implementation plan	WP5	4 - VUT	Report	Public	24
D 5.3	Interface and adapter specifications	WP5	4 - VUT	Other	CO	24
D 5.4	Implemented and tested interfaces	WP5	4 - VUT	Other	CO	28
D 5.5	Deployed smart factory solution	WP5	4 - VUT	De-monst-rator	CO	48
D 6.1	Evaluation framework	WP6	12 - ITA	Report	Public	20
D 6.2	Evalution environment defintion and setup	WP6	12 - ITA	Report	CO	36
D 6.3	Industrial Challenges specific evalua-tion reports	WP6	12 - ITA	Report	Public	45
D 6.4	Final evaluation report	WP6	12 - ITA	Report	Public	48
D 7.1	Project Website and Public Network-ing	WP7	7 - SIA	DEC	Public	6
D 7.2	Dissemination and Exploitation Plan	WP7	7 - SIA	DEC	Public	6
D 7.3	Activities Report (1)	WP7	7 - SIA	DEC	Public	12
D 7.4	Activities Report (2)	WP7	7 - SIA	DEC	Public	24

D 7.5	Activities Report (3)	WP7	7 - SIA	DEC	Public	36
D 7.6	Activities Report (4)	WP7	7 - SIA	DEC	Public	48
D 7.7	Business Plan	WP7	1 - VIF	Report	CO	30
D 8.1	Project Handbook	WP8	1 - VIF	Report	Public	1
D 8.2	Kick-off Meeting Report	WP8	1 - VIF	Report	Public	3
D 8.3	Data Management Plan	WP8	1 - VIF	Report	Public	6
D 8.4	Quality Management Plan	WP8	1 - VIF	Report	Public	6
D 8.5	Periodic Report (1)	WP8	1 - VIF	Report	Public	12
D 8.6	Periodic Report (2)	WP8	1 - VIF	Report	Public	24
D 8.7	Periodic Report (3)	WP8	1 - VIF	Report	Public	36
D 8.8	Final Project Report	WP8	1 - VIF	Report	Public	48
D 8.9	Mid-Term-Meeting Report	WP8	1 - VIF	Report	Public	26

Figure 24: List of deliverables

Milestones

As described in the Annex 1, there have been milestones defined to assure project quality. All milestones have been discussed during the Executive board meetings. As a documentation, for all milestones the responsible partner has elaborated a milestone description and achievement justification document.

Milestone Number	Milestone Title	WP number	Lead beneficiary	Due Date (in months)	Means of verification
MS1	Project kick-off wrapped-up	WP8	1 - VIF	2	Project kick-off wrapped-up
MS3	Architecture for smart factory worker- and data-centred building blocks	WP1, WP2, WP3, WP4	4 - VUT	10	Peer Review with developers
MS2	Collection and analysis of Organisational and worker-centric requirements I	WP1	8 - UZH	12	Collection and analysis of Organisational and worker-centric requirements I

MS4	FACTS4WORKERS prototype I	WP2, WP3, WP4	12 - ITA	24	Integration testing, friendly user tests
MS5	Mid-term-evaluation	WP1, WP2, WP3, WP4, WP5, WP6, WP7, WP8	1 - VIF	26	Report and EC feedback
MS6	Evaluation of requirements and prototype I	WP5, WP6	12 - ITA	26	Deployment and evaluation (log-analysis, thinking aloud tests, emotion tracking, …)
MS7	Refined requirements and industry challenges I	WP1	8 - UZH	28	Peer Review with workers, managers and developers
MS8	Business Plan	WP7, WP8	1 - VIF	30	Peer review of all Full-Partners
MS9	FACTS4WORKERS prototype II	WP2, WP3, WP4	6 - IMI	36	Integration testing, friendly user tests
MS10	Evaluation of requirements and prototype II	WP5, WP6	4 - VUT	38	Deployment and evaluation(log-analysis, thinking aloud tests, emotion tracking, …)
MS11	Refined requirements and industry challenges II	WP1	8 - UZH	40	Peer Review with workers, managers and developers
MS12	FINAL FACTS4WORKERS prototype	WP2, WP3, WP4	3 - UFI	46	Integration testing, friendly user tests
MS13	Final Evalution conducted	WP5, WP6	4 - VUT	48	Deployment and evaluation (log-analysis, thinking aloud tests, emotion tracking, …)

Figure 25: List of milestones

Use of resources

The proposed budget has been proven to be well planned, thanks to the intensive project planning during the proposal phase. However, the high workload due to the extreme business workload of the industrial partners caused resource problems, mainly in the Industrial Partners IT-departments. The missing resources have been compensated as good as possible by the scientific and implementing partners in order to keep the project going. The shifts of resources have been agreed within the consortium during the General Assembly meetings and agreed with the project officer Pauliina Hannele-Kavonius. As the DoA in the Annex 1 has not been modified, according to the financial guidelines, no amendment has been necessary and initiated (in line with PO´s opinion). However, as a result of the resource bottlenecks, one Use-Case has been shifted from one Schaeffler plant (Ingolstadt) to another (Schweinfurt) still covering the objectives of the Use-Case.

2 Update of the data management plan

A DMP (D8.3) has been set up. However, at this stage of the project there has no data been assigned for public provision. However, in Projectplace a central document repository has been made available wherein all project relevant documents are made accessible to the relevant team and consortium members.

It must be noted, that all personal and observation data from the workers involved in the evaluations of mockups, demos and prototypes are NOT available neither to the whole consortium, nor to the management of the respective industrial partner. These data are securely managed by UZH and the coordinator on a separate and secure server.

Due to the constant evaluations based on the described Digital Work Design Approach and on the other hand the Industry Partner specific implementations in productive productions lines instead of offline prototype lines, the relevant analysis data cannot be made publicly available. However, to test the available applications in our marketplace, neutral test data is available in some cases. If needed, please contact the coordination team at Virtual Vehicle at facts4workers@v2c2.at

3 Deviations from Annex 1

There are no deviations from the Annex 1 with respect to the work to be carried out.

ABOUT THE PROJECT

The high ambition of the project FACTS4WORKERS is to create Factories of the Future with a pervasive, networked information and communication technology that collects processes and presents large amounts of data. These smart factories will autonomously keep track of inventory, machine parameters, product quality and workforce activities. But at the same time, the worker will play the central role within the future form of production. The ambition of the project is to create »FACTories for WORKERS« (FACTS-4WORKERS), to strengthen human workforce on all levels from shop floor to management since it is the most skilled, flexible, sophisticated and productive asset of any production system and this way ensure a long-term competitiveness of manufacturing industry. Therefore a serious effort will be put into integrating already available IT enablers into a seamless and flexible Smart Factory infrastructure based on work-centric and data-driven technology building blocks.

These solutions will be developed according to the following four industrial challenges which are generalizable to manufacturing in general:

• Personalized augmented operator,

• Worked-centric rich-media knowledge sharing management,

• Self-learning manufacturing workplaces,

• In-situ mobile learning in the production.

Deviations from Annex 1

PROJECT PARTNERS

The FACTS4WORKERS project is composed
of 15 partners from 8 different European countries:

Virtual Vehicle Research Center	Austria
Hidria TC Tehnološki center d.o.o.	Slovenia
Universita degli Studi di Firenze, Department of industrial Engineering	Italy
Technische Universität Wien	Austria
ThyssenKrupp Steel Europe AG	Germany
Hidria Rotomatika d.o.o., Industrija Rotacijskih Sistemov	Slovenia
iMinds VZW	Belgium
Sieva d.o.o.	Slovenia
University of Zurich, Department of Informatics	Switzerland
Thermolympic S.L.	Spain
EMO-Orodjarna d.o.o.	Slovenia
Evolaris Next Level GmbH	Austria
Itainnova - Instituto Technologico de Aragon	Spain
Schaeffler Technologies AG & Co. KG	Germany
Lappeenranta University of Technology	Finland

PROJECT COORDINATOR / CONTACT:

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FINAL Report