Project Deliverable 1.3

Detailed and Refined Industrial Challenges, version I

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Layout and Setting: Florian Ott, Cooperation Systems Center Munich

FACTS4WORKERS: Worker-Centric Workplaces in Smart Factories

E-Mail: facts4workers@v2c2.at
Internet: www.facts4workers.eu

About this document

Executive Summary

This document represents Deliverable 1.3 “Detailed and Refined Industrial Challenges, version I” of the H2020 project “FACTS4WORKERS - Worker-Centric Workplaces in Smart Factories (FoF 2014/636778).

FACTS4WORKERS will develop and demonstrate workplace solutions that support the inclusion of increasing elements of knowledge work on the factory floor. The objectives of FACTS4WORKERS can be summarized as follows (according to DoA, 2014):

- To increase problem-solving and innovation skills of workers participating in the pilots of industrial partners
- To increase cognitive job satisfaction of workers participating in the pilots, and to improve their working conditions in terms of safety, work organization and well-being
- To increase average worker productivity by 10 % for workers participating in pilots, and the evolving role of the worker
- To achieve a number of worker-centric solutions through which workers become the smart element in smart factories, interacting by deploying a flexible smart factory infrastructure

This deliverable (D1.3) introduces the key production models in general and the related methods that manufacturing companies are applying. Four **Industrial Challenges** (IC) from Industrial Partners are introduced, which are also generalizable to other companies in the manufacturing industry. The industrial challenges are intended for testing and prototyping the smart factory building blocks at the forerunners’ factories and then transferred to the factories of followers. The Industrial Challenges presented in this deliverable are the following (according to DoA, 2014):

- IC1: **Personalized augmented operators** 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**: ICTs adopted in factories are neither successful in capturing knowledge, nor do they support social interaction and learning. Such knowledge management systems (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 by using rich media through the KMS, which is especially valuable for SMEs.

The industrial challenges will be understood and managed in order to achieve the objectives of FACTS4WORKERS project. First, the objective is to offer immediately and specifically visualized information to the workers via different kinds of Augmented Reality -tools. Secondly, a knowledge management system (KMS) for workers will be developed to support knowledge sharing and innovativeness in an open environment. Thirdly, one of the objectives is to establish self-learning manufacturing workplaces to speed up the analysis process of production parameters and the decision process of the responsible worker. Fourthly, an on-the-job learning environment should encourage shop floor workers to be more context-aware in real-life situations, in order to handle with the requirements of flexible production. (Unzeitig et. al., 2015)

The objective of this deliverable is also to match the Industrial Challenges with Industry Specific use cases. In addition, emergent themes and trends in manufacturing are described in order to assure that our solution approaches in the project will correspond with the future trends. This is the first version of the detailed Industrial Challenges and the deliverable will be refined after each year of the FACTS4WORKERS project as the Industrial Challenges evolve.

Document authors and reviewers

The following persons have contributed directly to the document. Please note that many other people have also supported our work, and we thank them all sincerely.

Lead Authors

Name	Organisation	Role
Dr. Lea Hannola	Lappeenranta University of Technology	WP 1, Task 1.2 Lead
Dr. Antero Kutvonen	Lappeenranta University of Technology	WP 1
Dr. Ville Ojanen	Lappeenranta University of Technology	WP 1
Jorma Papinniemi	Lappeenranta University of Technology	WP 1

Featuring Authors

Name	Organisation	Role
Dr. Hannele Lampela	Lappeenranta University of Technology, University of Oulu	WP 1

Reviewers

Name	Organisation	Role
Martin Wifling	Virtual Vehicle Research Center	WP 8 Lead, Project Coordinator
Dr. Alexander Richter	University of Zurich	WP 1 Lead

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AR	Augmented Reality
ATO	Assemble-to-Order
BIM	Building Information Modeling
CAD	Computer-Aided Design
CMS	Content Management System
CNC	Computer Numerical Control
CPS	Cyber-Physical-Systems
CRISP-DM	Cross Industry Standard Process for Data Mining
CTO	Customize-to-Order
DSS	Decision Support Systems
EMO	EMO Orodjarna d.o.o
ERP	Enterprise Resource Planning
ETO	Engineer-to-Order
FoF	Factories of the Future
F4W	FACTS4WORKERS
GPS	Global Positioning System
GUI	Graphical User Interface
HCI	Human-Computer Interaction
HID	Hidria TC d.o.o
HIR	Hidria Rotomatika
HMD	Head Mounted Display
HMI	Human Machine Interface
HR	Human Resources
IC	Industrial Challenges
ICT	Information Communication Technology
IoT	Internet of Things
IP	Industrial Partner
IS	Information System
JIT	Just In Time production
KM	Knowledge Management
KMS	Knowledge Management System
KPI	Key Performance Indicator
LE	Low Energy
MES	Manufacturing Execution System
MTO	Manufacture-to-Order

NFC .... Near Field Communication

OEE .... Overall Equipment Effectiveness

PDM .... Predictive Data-Mining

RFID .... Radio-Frequency IDentification

SCA .... Schaeffler AG

SCADA .... Supervisory Control And Data Acquisition

SLAM .... Simultaneous Localization and Mapping

SME .... Small and Medium sized Enterprises

SOA .... Service Oriented Architecture

THO .... Thermolympic S.L.

TKSE .... ThyssenKrupp Steel Europe AG

TPM .... Total Productive Maintenance

UWB .... Ultra-Wideband

UX .... User Experience

VSM .... Value Stream Mapping

WGC .... Worker Generated Content

1 Introduction

Manufacturing companies have changed radically over years and the trend will certainly continue. The growing demand for new, innovative and high quality products, intensive competition, and the trend towards mass customization are influencing the development of production systems and how products are manufactured. Companies in the automotive industry are especially sensitive to production disruptions and sudden production changes due to the multiplicity of demands that they are required to comply to. This has caused the emergence of new manufacturing technologies, which require highly agile and flexible manufacturing environments. According to Yew et al. (2016), human workers are an essential part of the manufacturing environment and they also have to be flexible and motivated to utilize the possibilities of new technologies and production models. This trend has encouraged companies in the manufacturing industry to invest in new and more integrated monitoring and control systems for optimizing their production processes more and more to assist a quicker fault detection that will reduce production down-times while improving system performance and throughput in terms of time (Orio et al., 2015).

There are different needs, strategic choices and decisions in different organizations that typically determine the chosen method for production. This deliverable (D1.3) introduces the key production models in general and the related methods that manufacturing companies are applying. Each of the production methods has specific challenges and recommendations related to improving the productivity of the workplace.

This deliverable reports on four Industrial Challenges (IC) chosen from Industrial Partners of FACTS4WORKERS, which are also generalizable to other companies in the manufacturing industry. These four Industrial Challenges are 1): Personalized augmented operator, 2) Worked-centric rich-media knowledge sharing/management, 3) Self-learning manufacturing workplaces, and 4) In-situ mobile learning in the production. These challenges are depicted in Figure 1.

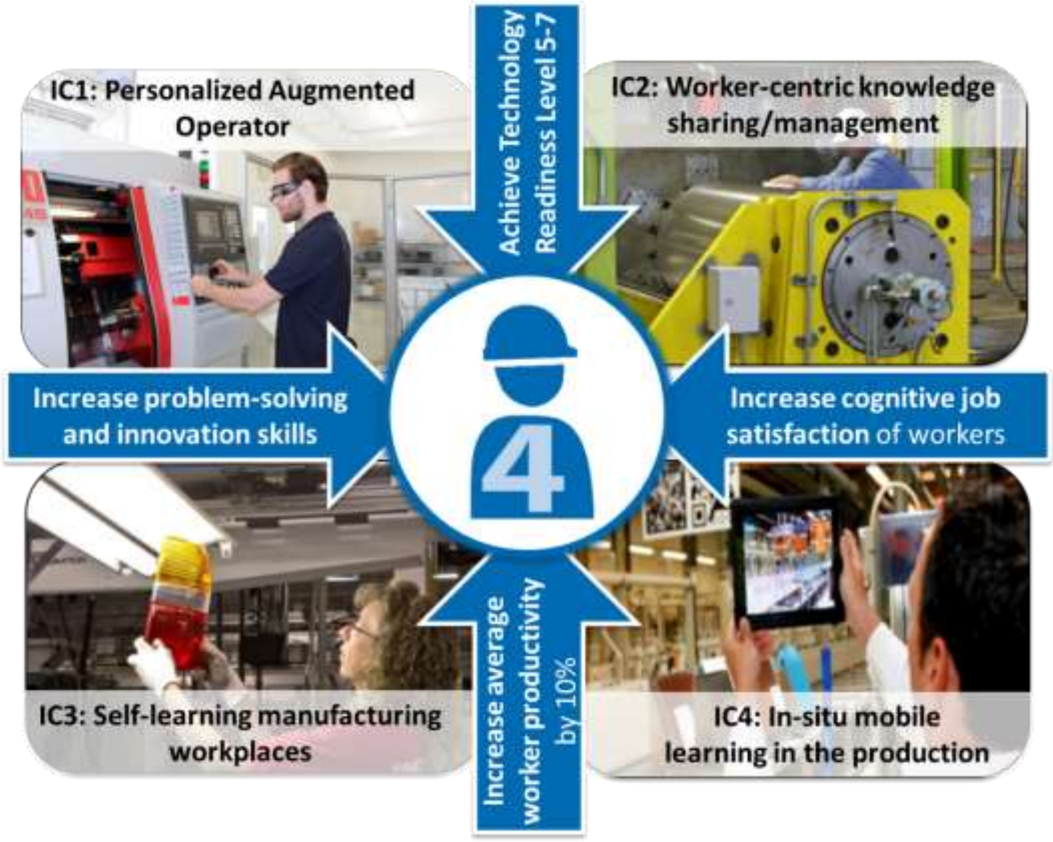


Figure 1 The four Industrial Challenges (DoA, 2014)

These four smart factory Industrial Challenges serve for the demonstration and evaluation of the complete concept in FACTS4WORKERS. Though Industrial Challenges can only give an exemplary view on a Smart Factory of the Future, they are proposed to be transferable to other companies in the manufacturing industry, especially to SMEs. First, the Industrial Challenges are intended for testing and prototyping the smart factory building blocks at the forerunners' factories and then transferred to the factories of followers. Taking such an approach will ensure a working transfer of the developed smart factory building blocks into other manufacturing industries. The four Industrial Challenges (IC1 – IC4) are defined at the factories of industry partners (HIR, TKSE, EMO, HID, THO and SCA), yet generalizable to other manufacturing environments.

The deliverable focuses more on the technological requirements rather than the organisational or processual ones. However, new ways of work and production models, extended decision responsibilities and innovation skills will lead to further changes in the factory organizations. Thus, these aspects are also briefly addressed in the document.

The objective of this deliverable is also to match the Industrial Challenges with Industry Specific use cases in the industrial partners' production environments. In addition emergent themes and trends in manufacturing are described in order to assure that our approach in the project will coincide the future trends. This is the first version of the detailed Industrial Challenges and the deliverable will be refined after each year of the FACTS4WORKERS project as the Industrial Challenges evolve.

The rest of this Deliverable is structured as follows. Section 2 describes the production models in manufacturing in general and the key methods for the maximization of value for the customer. Section 3 introduces the four Industrial Challenges and IC-specific requirements, technologies and methods. In Section 3, the Industrial Challenges are matched with Industry Specific use cases. Emerging trends and themes in manufacturing are described in Section 4. Finally, Section 5 summarizes the document and the key learning and recommendations are described.

2 Production models in manufacturing

This chapter summarises the actual state-of-the-art of the production models in manufacturing for our internal developments.

2.1 Strategic choices in production models

Strategic choices and decisions on products, services and production guide strongly what kind of production models and related methods a manufacturing company is applying. In different industries there are different needs, e.g., an order-based, a product-variety -based, or a volume-based production model, which typically determine the chosen method of production. In general, production methods can be classified as:

- Project-based production (low volume – high variety)
- Job production
- Batch production
- Flow production / Just-in-time production (JIT)
- Continuous /Mass production (high volume – low variety)

In order to describe the relation of volume and variety, *the high variety*, may cover e.g. hundreds to thousands of active parts or components, a few with active estimated volume. *A low volume* lot size is dependent on the customer, e.g. usually a small order size.

The strategic choices of production models are highly determined by *the level of customization in the manufacturing company*. The degree of customer alignment is determined by the customer coupling point and the amount of customer-oriented information (Forza et al., 2007), see Figure 2. If the customer is involved already in the early phases of the business process (from design, manufacturing, assembly, to distribution), more customer connection and information is required.

In pure customization, the most intensive customer alignment is accomplished by the Engineer-to-Order (ETO) strategy and products. ETO strategy in production is suitable for unique products that have similar characteristics, and the production is initiated when receiving a customer order and developing technical specifications accordingly. (Silventoinen et al., 2014)

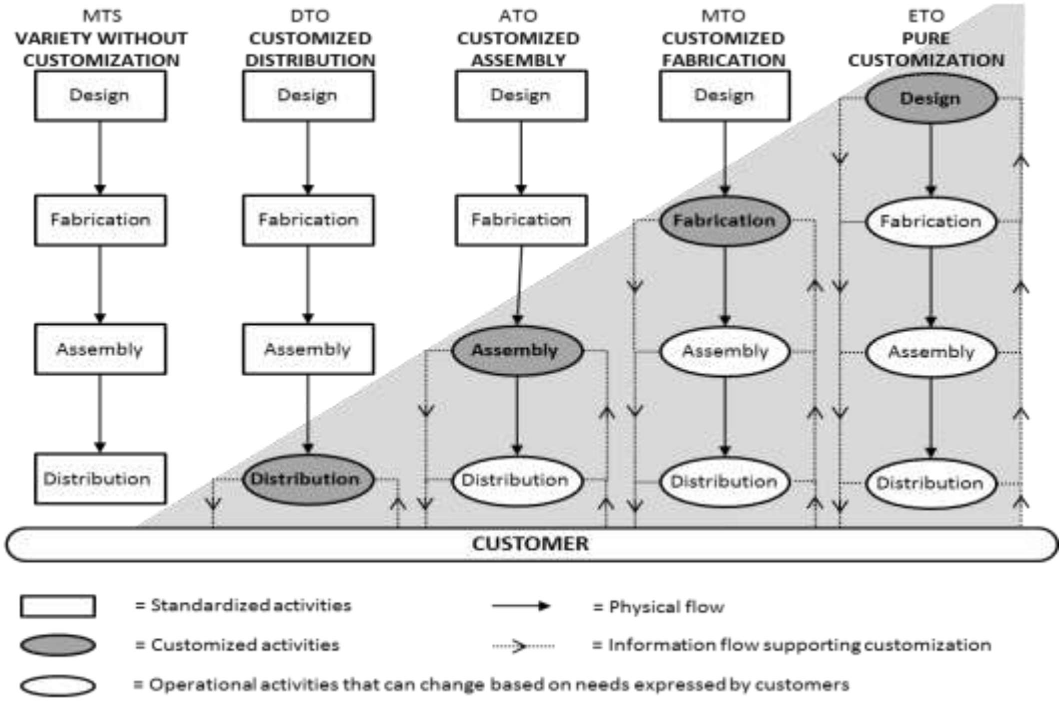


Figure 2. Customization of product and production strategy (adapted from Forza et al., p.10)

In Manufacture-to-Order (MTO) strategy, the customer requirements influence directly the manufacturing activities, not the design process. The company usually offers to the potential customers a base product that is later modified according to the customer's preferences without modifying the basic design. So, the degrees of flexibility and the modifications that may change the base product are defined in advance.

An important customer-centric strategy in manufacturing is Assemble-to-Order (ATO) or Configure-to-Order (CTO) strategy. In these cases, the customer requirements effect directly on the assembly activities, not on the design and manufacturing processes. Products are manufactured with a set of regular components and parts, but the assembly process of this set is customized to fulfill the detailed customer needs. (Forza et al., 2007)

2.2 Shop floor management system and its links

Manufacturing companies today are encountering a rising number of product variants along with personnel ageing due to the demographic change. These challenges necessitate companies to develop their employees' competencies – in particular problem solving competencies on the shop floor. So as to support a value-driven material and product flow, shop floor management systems have been implemented in many manufacturing environments (see Figure 3). In order to continuously develop problem solving competencies, the integration of a competency management system has been introduced through shop floor management.

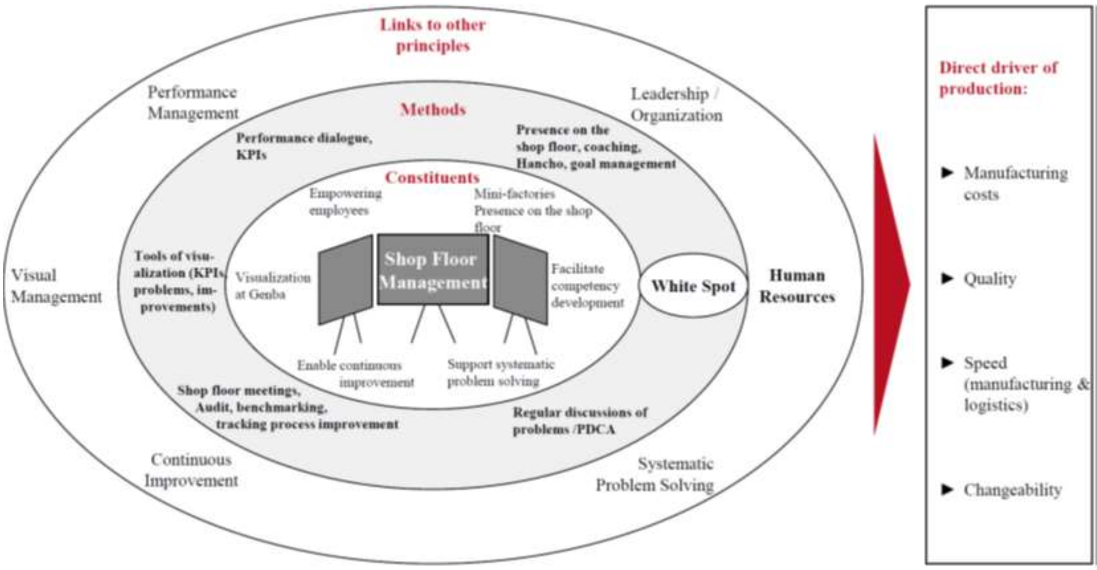


Figure 3. Shop floor management system and its links to other managerial systems (Abele et al. 2011; Hertle et al., 2015, p. 3)

The aims of shop floor management are achieved by utilizing the different elements of the shop floor management system. Shop floor management components have been identified by a majority of authors. Shop floor management is described by the Japanese word Genba, which is the place where value is created. As the responsibility areas of managers have been growing, they tend to spend more time in the office and closed meeting rooms. In order to compensate this, the daily routines of managers should be changed and shift meetings to be arranged and on the shop floor. By these strategy changes, the management could be better recognized at the shop floor, which could increase the motivation of the workers and enhance the problem solving process. (Hertle et al., 2015)

2.3 Lean manufacturing methods

Lean manufacturing, or sometimes merely "Lean", can be defined as a production practice whose primary targets are to maximize *value for the customer* and to *eliminate production wastes*. Value can be defined as the ability to make products or services available at the right time and at the proper price for fulfilling a customer's needs. For that reason, value can only be assessed by the customer, and it should be the basis of lean thinking (Womack and Jones 2003; Lacerda et al., 2015).

Some of the many Lean strategies, methods and tools are presented in Figure 4, which is one adaption of the graphic often called the 'Toyota house", facilitating users to visualize the system.

Figure 4. Lean Manufactory House (Van Lieshout, 2006)

Lean strategies. Starting at the top, it identifies the high-level, ongoing, and constant goals for customers and employees, improvements in quality, and reduction in cost, delivery and lead times. These are the outcomes of applying the strategies shown as two pillars: just in time (JIT) and Jidoka.

Just in time (JIT) is the strategy of doing all work phases at the rate of customer demand. Originally it referred to the production of goods in time, at quality and quantity to exactly meet customer demand, whether the `customer' was any participant in the production line along the supply chain. Its meaning has now changed to producing with minimum waste. "Waste" is used here in its most general meaning, and including time and resources as well as materials. (JIT, 2016).

Jidoka is the strategy of understanding and eliminating the root cause of all defects to drive improvement. Jidoka is a Japanese word that means 'automation with human touch', including four main principles: (1) detect the abnormality, (2) stop the process, (3) fix the immediate condition, and (4) investigate the root cause. (Kaplan, 2008)

These strategies are implemented by using an ever-evolving variety of methods/tools, such as standard work, visual management and 5S. While most of the activities that are discussed in the Lean world are the result of JIT (e.g., improved lead times, lower inventories, on-time deliveries), the enabler for this ongoing improved performance is Jidoka. Eliminating defects or waste has always been a management goal, but hidden defects are nearly always overlooked. Hidden problems are the ones that may eventually become serious threats. If problems can be visualized, it is easier to find solutions to them.

Lean principles. 1) The *definition of value* is regarded to be the first of the five lean principles. 2) The second principle is the *identification of the value stream*, which includes all the particular actions for developing and manufacturing a product or delivering a service. 3) The third lean principle is *flow*: after the value definition, the value stream mapping for a specific product and the elimination of wastes, the products should flow through the rest of the value-adding steps. 4) The fourth principle is *pull*, which indicate that customers are allowed to pull the product along with their needs instead of pushing unsuitable products to the customers. 5) Finally, as value has been specified, the value streams are identified, wasted stages removed, and flow and pull principles have been introduced, the lean process will start from the beginning and will carry on until *a state of perfection* is achieved. The perfect value is created when there is no waste (Lacerda et al., 2015; Womack and Jones, 2003).

Lean methods and tools. There are varying perspectives to how the goals and principles described above can be achieved best, and what kind of methods and tools for Lean could be applied in different situations and application areas:

- Value Stream Mapping (VSM), Process Mapping
- The 7 wastes (Muda)
- 5S (Sort, Straighten, Shine, Standardize, and Sustain)
- Kaizen
- Kanban
- Chaku-chaku
- Poka-yoke
- Total Productive Maintenance (TPM)
- Lean and Performance Management (Lean KPI)

Value Stream Mapping (VSM) is a method that facilitates visualization and understanding of the material flow and related information throughout the value chain. It enables a holistic picture of the activities, which are involved in the production process, and it thus supports the identification of the waste sources. Quicker response time to the customer, lower production costs and higher quality of products are thus possible outputs that are probable when utilizing a VSM method to a production process. Participation from key units in organization is essential to obtain necessary information of the production processes. Once the ‘current state’ is mapped with identifying the wastes in the process, the mapping of the preferred ‘future state’ can be done, together with the action plan by which to accomplish it. (Lacerda et al., 2015)

The 7 wastes. The idea is that when waste is eliminated, quality increases, while production time and costs are simultaneously reduced. The Japanese word, *Muda,* meaning for waste, refers to any activity that does not enhance any value to a product. There exist three kinds of value-related activities in an industrial environment. One of them adds value to the final product and should thus be maintained. Another type activity is the non-value adding but inevitable (type one muda) that should be examined and, if possible, condensed. The third type activity is the non-value adding and not inevitable (type two muda) that should be removed. (Lacerda et al., 2015)

Ohno (1988) has originally recognized the seven common wastes in industrial environment, which are briefly described below, according to Lacerda et al. (2015) and Womack and Jones (2003):

- *Defects* – Quality problems are usually caused by the lack of standard procedures and quality control systems, or by human failure. They can often cause complaints from customers or they can be discovered by inspection or maintenance teams, and therefore have a negative influence on production costs as well as productivity.
- *Waiting periods* – Time is wasted when waiting for materials, people or equipment. This can occur due to flow interruption, delays in the delivery of components, unbalanced production processes or problems around the layout of stations
- *Inventory* – Additional inventory is usually caused from the production bottlenecks, slow setup times or unbalanced processes. Therefore, larger storage areas and more handling actions are required.
- *Motion* – The movement of a worker does not add any value to the product. This is often associated with the placing of components or tools within the station or to ergonomic viewpoint that request bigger efforts from the workers.
- *Over processing* – Any operation or process that exceeds the need of processing power can be considered production waste and can potentially cause defects in products, therefore not adding value to the company.
- *Overproduction* – Overproduction means the production of more product items than are required by the customer. Therefore, additional working capital is bound to inventory, stock and essential warehouse space increase, and production planning turns out to be less flexible.
- *Transportation* – Additional moving of products, items and materials inside a factory necessitates transportation arrangements that can be expensive, need maintenance activities, increase lead time, and sometimes can damage parts.

Recently, an additional type of waste, *talent*, has been highlighted as important (Lacerda et al., 2015; Liker and Meier 2006), and therefore it should be included in the list of wastes.

- *Talent* – The waste of human potential can result in missed improvement opportunities, as according to lean thinking every individual can contribute with positive outcomes (Lacerda et al., 2015).

***5S** (Sort, Straighten, Shine, Standardize, and Sustain)* is a method for increasing productivity. The name of the method is derived from the five first letters of the Japanese words: Seiri, Seiton, Seiso, Seiketsu and Shitsuke. The original intention of the method was to organize a workspace for efficiency. The 'S's are described by Parker (2012) as follows:

- *Seiri – Sort*. Keep only the necessary things in the working area, arrange or keep the items that used less frequently in a distant storage area, and abandon unnecessary items.
- *Seiton – Straighten.* Arrange systematically the most efficient and effective retrieval of items. Everything should have its own place and everything should be kept in its own place. The correct place for each item should be clearly labeled or established. Items should be arranged in a manner to promote efficient workflow, with the equipment most regularly used being the most easily accessible. It should not be the workers' main job to repetitively access materials.
- *Seiso – Shine.* Keep the workspace and all equipment cleaned, tidy and organized. When implementing 5S, after the first thorough cleaning, follow-up of daily cleaning is necessary for sustaining this improvement. A "Shining" work environment enables greater efficiency gains.
- *Seiketsu – Standardize*. Work practices should be reliable and standardized, allowing all employees to do the same job in any work station with the same tools that are in the same location in every station. The work stations for a specific job should be similar. Every worker should recognize their responsibilities precisely.
- *Shitsuke – Sustain.* After the previous four S's have been established, also the new way to operate will be applied. The focus on this new way must be maintained and gradual return to the old habits is not allowed. The effect of continuous improvement (Kaizen) results in less waste, faster lead times and better quality.

Kaizen is a system for "*continuous improvement*" that comprises all employees – from top management to the shop floor level. Every employee is encouraged to participate with ideas for small improvements regularly and on-going basis. Kaizen contains the setting of standards and the improvement of those standards continually. According to Parker (2012) the cycle of kaizen activities can be identified as follows:

- Standardize operations and activities
- Measure the standardized operation (the cycle time and in-process inventory)

- Measure measurements against requirements
- Innovate to fulfill requirements and improve productivity
- Standardize the new and improved operations
- Continue the cycle of kaizen constantly: the main elements of kaizen are quality, effort, participation of all employees, readiness to change, and communication

Kanban is a Japanese word for "*visual signal*" or "card". This Kanban based system enables work teams to communicate more straightforwardly on which work needs to be completed and what time. E.g. Toyota line-workers have used a kanban cards (i.e., an actual card) to point steps in their manufacturing process. It also standardizes indications and refined processes, which helps to minimize waste and maximize value. According to Leankit (2016), Kanban supports the power of visual information by using sticky notes on a whiteboard to create a "picture" of the work. Being able to see how one's work flows within the team's process, lets people not only communicate the status but also provide and receive context for the work. Kanban cards include information that would typically be communicated via words. The four Kanban principles are (Leankit, 2016):

- Visualize work
- Limit work in process
- Focus on flow
- Continuous improvement

Chaku-chaku is a principle where a worker is assigned to each produced unit and takes the piece personally from one workstation to the next throughout the whole process, assuming responsibility for setting up and operating each machine on the way. This is most applicable in single-piece manufacturing with low specialization level of production machinery – it requires expertise in operating each machine and causes inefficiencies due to worker movement.

Poka-yoke is a principle of utilizing `foolproof' tools, methods, jigs etc. to prevent mistakes***.***

Total productive maintenance (TPM). This is preventative maintenance that ensures that the machines and equipment function perfectly when needed, and continually improves it.

Lean and Performance management (Lean KPI). What kind of performance indicators measure the success in lean initiatives best? It is important for companies to understand how key performance measures can direct and accomplish a company's execution towards greater results in any manufacturing areas. (Bhasin, 2008)

2.4 Six Sigma and Production process

Six Sigma and Lean can be considered as compatible families of techniques, where Six Sigma removes errors from processes and Lean removes waste (Conger, 2010). Process management and improvement require *leaning,* i.e. removal of unnecessary steps for improvement, *cleaning,* i.e. the simplification and step level leaning of the remaining steps, and *greening*, i.e. the potential use of outsourcing, co-production, or automation (Conger, 2010). The following set of basic Six Sigma techniques can be applied within above mentioned areas of analysis:

- Process mapping
- Problem identification: check sheets and other manual forms
- Pareto Analysis Diagram and other graphics
- Failure Mode of Effects Analysis (FMEA)
- Cause and Effect (Ishikawa) Diagram
- Root Cause Analysis (RCA)
- Value Added Analysis (VAA)
- Quality Function Deployment (QFD)

According to Conger (2010), the objective of Six Sigma is to improve the expected quality of products as well as services by removing normally distributed faults. Six Sigma techniques are usually applied to a comprehensive variety of problems and they are used as representatives of the reasoning used for process improvement.

3 Industrial Challenges (IC)

3.1 IC1 - Personalized Augmented Operator

Growing customization and reducing lot sizes (down to lot size =1) in production involve major variability in daily manufacturing work. Together with the complexity of assembly across the entire automotive value chain (e.g., in car interior manufacturing or production of 3D steel or plastic components), the operators and production workers need to deal with a growing number of specified and quickly changing information from various sources, while working requires two hands for operation. The production information comes from several sources, such as information from a roll-form plant, from sophisticated design and diverse suppliers, as well as real-time input data from machine sensors. The challenge is created in offering and effectively utilizing information that is ever more complex, combined from multiple sources and types, and changing constantly, while dealing with the traditional demands of the production environment, such as two-handed operation.

As Cyber-Physical-Systems (CPS) connect physical and digital production systems, the Augmented Operator grows in relevance. In quickly changing, re-adaptable production lines, when rapid prototyping technologies (e.g. 3D-printing) begin to be introduced in warehouses and on the shop-floor, job descriptions, orders and the interlinked production processes grow in complexity.

Personalized Augmented Operators 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. AR is defined e.g. as "*a novel human-computer interaction tool that overlays computer-generated information on the real world environment*" (Nee, et. al. 2012, p. 657), or as "*a state-of-the-art technology for superimposing information onto the real world"* (Chi et al. 2013, p. 116). In FACTS4WORKERS, the Augmented Operator has a wider definition, i.e. Augmented Operator means not only AR, but also provides all illuminating information to the workers, which could also be provided by other means.

3.1.1 Augmented Reality

According to Nee et al. (2012), AR technologies have proven to be effective solutions and matured enough in helping to solve some of the serious problems in simulating, assisting and improving manufacturing processes before they are realized. This would make sure that activities, e.g. design or machining, are executed correctly at the first time without any need for re-work and modifications (Nee et al., 2012). In addition, AR can be integrated with human capabilities to provide efficient and complementary tools to support manufacturing tasks. The manufacturing applications of AR cover product design, layout planning, assembly, maintenance, robotics and machining (Yew, et al., 2016). However, Nee et al. (2012) point out that AR in design and manufacturing processes is a rather new application area compared to some of the entertainment applications. This is mostly because of the accuracy required in tracking and registration in these kinds of applications, and a good alignment with traditional practices (Nee, et. al. 2012.) However in the next ten years, according to Chi et al. (2013), AR technologies will be developed enough to be widely applied also in the industrial sector. Potential technologies for developing AP applications related to the cloud computing environment, localization, portable and mobile devices, and natural user interface are presented in Figure 5.

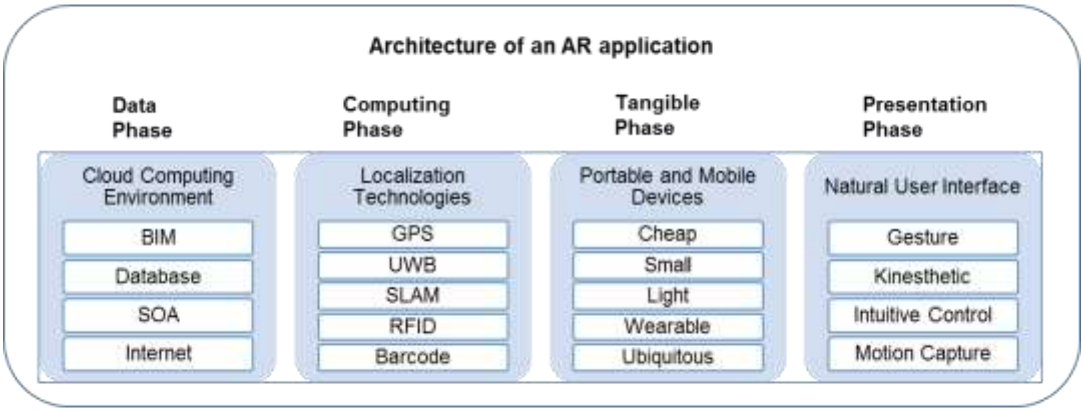


Figure 5. Potential technologies for the development of AR applications (Chi et al., 2013, p.118)

Currently, workers rely primarily on paper checklists generated from MES/ERP systems, in order to receive exact job descriptions or orders. As a result, work may paradoxically suffer from information overload or lack of pertinent information. Context-relevant information displayed in the line of sight without media breaks, and seamless interaction across different IT tools becomes crucial for smooth operation and avoidance of cognitive overload. Yew et al. (2016) have introduced a manufacturing system that substitutes all paper-based and computer-based activities with AR activities that are completed naturally by the workers in their physical work environment. In this system, the objects that the workers are interacting with are implemented as smart objects using the graphical user interfaces (GUIs), which are augmented onto the workers' perception of their work environment. Further, the features of GUI can be directly managed by hand, and they are used to characterize critical real-time information, which is specific to the objects and the task imminent to the worker. Workers can view and interact with the GUI using different viewing devices, such as tablets or wearable computers (see Figure 6). The objects (e.g. CNC machines or CAD designs) in the system can be physical or virtual and they can interact with each other to provide computer-aided technologies to the workers. An example of an overall system architecture of the system for a local environment, according to Yew et al. (2016), is depicted in Figure 7.

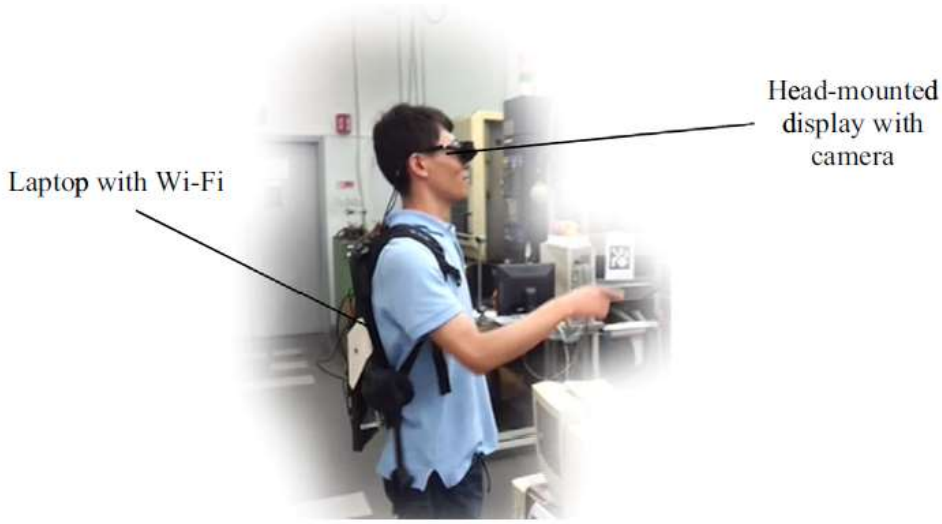


Figure 6. Wearable system to manage the AR environment (Yew et al., 2016, p. 47)

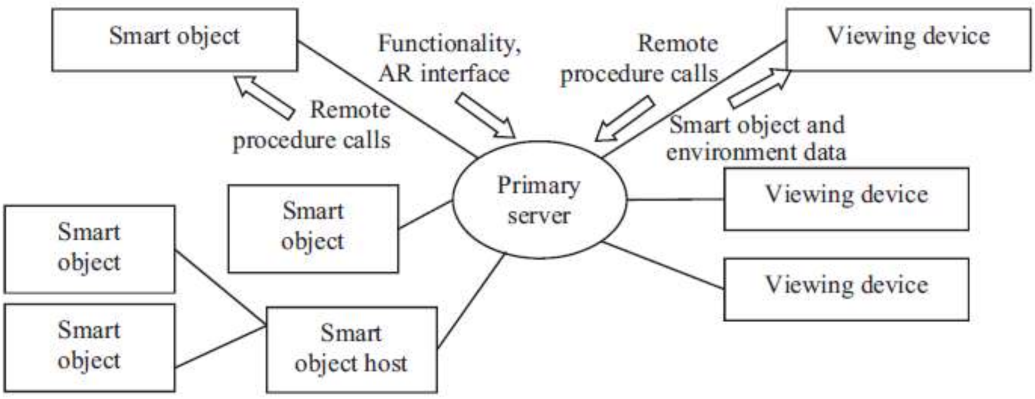


Figure 7. An example of a system architecture for a local environment (Yew et al., 2016, p. 44)

3.1.2 Industry Challenge -specific requirements, technologies and methods

IC-specific requirements:

- Better information visualization for hands-free operation in production lines
- Combination of intelligent data with seamless interaction/interfaces
- Assistance of workers by Augmented Reality (AR) content displayed in smart digital glasses/head-mounted display in changing production settings
- Personalization of information

Vision: Based on consequent tracking (e.g. RFID, Bluetooth LE) of product components at the lowest costs possible e.g. on the roll-form plant, different data sources are combined by a sensor- and non-sensor -based contextual data framework feeding into a personalized Augmented Vision assistance system.

The workers receive an immediate, machine-specific and personalized provision of information directly at the machine via their AR-enabled HMD based on the particular worker's role/profile. The visualization may include e.g.: seat type, material, design and necessary working steps, criteria for quality control and checklists.

Different multi-modal interaction types (e.g. voice, eye tracking, touch, 3D gestures) are necessary to address the key requirement of hands-free operation, combined with other input and output (e.g. micro projector, touchscreen devices, info screens) suitable for the production process. In the long-term vision ‘dumb’ protection glasses, which operators have to wear anyway due to work safety, may be replaced by ‘intelligent’ AR glasses, to support the worker in the provision of context-specific information.

IC-specific technologies and methods:

- Tracking of product components by indoor geo-localization techniques: e.g., RFID, Bluetooth LE, infra-red
- Auto-ID user identification: 2D-3D barcodes, NFC, Bluetooth (LE)
- Multimodal HCI/HMI concepts (e.g., voice, 2D/3D gestures) for maximized usability
- User Experience (UX) based on co-creation development with operators
- AR feature tracking for 1:1 picture overlay
- Multi-lingual speech processing for voice control
- Data-based production process modelling
- Connection to MES, ERP, SCADA data
- Sensor- and non-sensor based contextual data processing

Building blocks demonstrated in industrial challenge:

Smart factory layer	Building blocks
Worker interfaces:	HMD, other wearables, desktop, machine, screen
Services:	Intelligent Dashboard, Decision Support Systems (DSS)
Technologies:	Data mining, Semantics, Visual Framework
Data:	Worker-sensors, MES/ERP/SCADA, production data

3.2 IC2 - Worker-centric rich-media knowledge sharing and management

The Industrial Challenge, worker-centric rich-media knowledge sharing and management, is twofold. Firstly, the challenge is to equip the workers with efficient means to share and co-develop valuable work-related knowledge. On the other hand, since these tools have not been generally available so far, the practices and working models for utilizing them are undeveloped. Solving both sides of the challenge requires combining knowledge management, workflow design and ICT technology simultaneously to develop the solution in direct interaction with the workers.

However, the adoption of ICT tools to facilitate effective sharing, development and integration of knowledge in the shop-floor work is held back by the challenging environment-specific requirements to the design of tools that prevent the use of generic, off-the-shelf equipment. Knowledge sharing in a manufacturing company has the same relevance as in the office environment, but the applicability of ICT tools on the shop-floor implicates a lot of specific requirements:

- Interaction schemes need to be even more simple and intuitive (e.g., touch or gesture interaction instead of typing), taking also extreme conditions in production environments into account (e.g., extreme heat or noise)
- The tools need to be much more robust (e.g. “rugged devices”) and safety needs to be guaranteed throughout the whole production process
- Data and know-how security as well as the workers' privacy must be guaranteed

The challenge consists in introducing “open innovation 2.0” and knowledge sharing in production environments by most effective means. One of the industry partners in this project (TKSE) has already introduced, as one of few manufacturing enterprises, a knowledge management system to gather experiences and lessons learned from and for workers at the machine, and link them within a database setting high value on user acceptance. This platform not only allows a long-lasting preservation of knowledge, but facilitates job training and improves intra-organizational knowledge transfer among skilled workers in steel manufacturing. Considering the IT capabilities and know-how on human resources, the system can be elevated to a European best practice in Internet of Things/Everything enhanced worker-centric knowledge management.

3.2.1 Knowledge Management System

Modern manufacturing work is knowledge-intensive and benefits greatly from the introduction of professional knowledge management and sharing practices and tools. A knowledge management system (KMS) is developed for the specific needs and preferences of the manufacturing shop-floor workers. The system will facilitate social interaction and (peer) learning, as well as aid in managing and codifying key knowledge. The role of skilled shop-floor workers is more important than ever, because they are those who use the system, make sure that product specifications and deadlines are fulfilled, and keep the production running (Yew, et al., 2016). Despite widespread acknowledgment of the significance of the knowledge of workers at the shop floor, knowledge management research has not paid much attention to it (Nakano et al., 2013).

Adopting social software in the enterprise to facilitate knowledge work at office workplaces is a topic of research often coined as Enterprise 2.0 (Koch and Richter, 2009) or Corporate Social Software. Social Software has contributed to technology-enhanced knowledge management as it shares similar goals (Richter et al., 2013), and there already exists a series of industry cases where wikis (Stocker et al., 2012), weblogs and social networking are used to facilitate knowledge sharing and social interaction across group-, department- and organisational borders, but only in office-based environments. In current production, increasing social interaction among team members on the shop floor is a topic (see e.g. the principles of lean management), which is not yet supported by information technology. To stimulate interaction across teams, departments or production sites, new modes of using technology will be required. While so-called Social Software has been investigated in its potential to facilitate office work, there are still no scientific case studies where social media is reported to assist manufacturing collaboration in a production facility. As the project develops social media -based demonstrators to facilitate social interaction and worker-content generation on a larger scale, a significant advancement in case-study -based Social Media research is expected.

The transformation of social technologies to a production environment is one of the advancements of FACTS4WORKERS. This comprises the back-end of managing user-generated content as well as the way of generating content and interacting with the IS in a rugged production environment. Hence, there are two developments to be addressed in FACTS4WORKERS:

- First, the ability of the KMS back-end to handle rich-media content (store, search, combination)
- Second, a user interface which will be more in line with “YouTube for the factory floor”

Concerning the first point, tagging metadata generation of user-generated (multi modal) multimedia content by using semantic technologies like ontologies is one of the main issues that are currently not addressed adequately. The activities in the project will include workers sharing audio and video content with colleagues through automatically generated metadata (e.g., the mobile tablet knows the machine of a worker and captures it as metadata). Another approach is to include more context information into the captured or recorded material and then share the content to enhance its quality.

3.2.2 Industry challenge -specific requirements, technologies and methods

IC-specific requirements:

- Enable production workers to interact and share knowledge while adding value to raw materials
- Introduce Web 2.0 and Open Innovation into the shop floor
- Allow know-how exchange, especially between younger and senior workers

Vision: The Knowledge Management System in the Smart Factory needs to be designed as much more open to empower and motivate the workers to contribute know-how easily and actively to an always up-to-date knowledge pool. If a steel production worker, e.g. while cleaning a roll of stainless steel in preparation for sending the metal through the cold rolling mill has an idea or makes an observation – he/she should be able to use his/her mobile device spontaneously (e.g. rugged smartphone/tablet with NFC and/or Bluetooth LE capability, smart glasses) or interact at a mobile touchpoint (e.g. Internet of Things cube with integrated RaspberryPi and sensors) located within the factory to capture the idea/observation by several options of information collection and processing, as for instance:

- The worker takes a photo, creates a short video with a rugged smartphone and uploads it automatically semantically annotated to the KMS
- The worker interacts with a touch-enabled interaction cube (e.g. NFC based) giving commands like "YES/NO" just by touching a surface, also with worker gloves
- The worker describes a problem, recorded by voice recognition in smart glasses
- Additional sensor data can be "attached" (e.g., temperature, noise, machine parameters) to the report/idea/observation

After uploading the Worker Generated Content (WGC) to a company-internal cloud server, all the other steel workers also in other locations have the options:

- To read, listen and/or see the content

- To like, share, and rate the Worker Generated Content (WGC)

The KMS is assisted by gamification measures, incentivation and appropriate HR measures (e.g., the worker with the most Karma points gets an additional holiday week) to motivate workers for the usage of the KMS. Personalized to worker roles (e.g. trainee), additional information about machines, status of processes, documentation, service descriptions etc. are presented context-aware to the user-based on indoor geo-localisation and Auto-ID technologies. Augmented Reality is applied for e.g. 3D automotive components (CAD, 3D models) and allows 3D manipulation of objects, e.g. by gesture control. A cloud-based "tool set card" with indoor-navigation for mobile devices/wearables and suitable, cost-efficient tracking (e.g. BT LE) allow localizing, sharing and keeping track of equipment and tools in large production settings e.g. for maintenance or service.

In the long term, the vision is a factory where workers and workers (P2P), machines and workers (P2M, M2P), as well as machines and machines (M2M) interact naturally in an industrial social network, sharing their status, experience and information.

IC-specific technologies and methods:

- Mobile and cloud computing
- Co-creation with production workers
- Semantics, Linked Enterprise Data
- Social Media, Web 2.0, Social Software Integration
- New HCI/HMI concepts for wearables/mobile devices and 3D-AR content for direct manipulation
- Gamification and incentivation concepts for worker motivation
- Learning psychology
- Indoor geo-localisation and navigation

Building blocks demonstrated in industrial challenge:

Smart factory layer	Building blocks
Worker interfaces:	HMD, other wearables, desktop, machine, screen
Services:	Intelligent Dashboard, Social collaboration, workplace learning
Technologies:	Semantics, Social Software, Visual Framework
Data:	Worker-sensors, KMS, production data

3.2.3 Worker motivation for knowledge sharing

In addition to introducing new means and tools like Web 2.0, it is essential for organizations to recognize what motivates workers to share their knowledge and what prevents them for knowledge sharing. According to Paroutis and Saleh (2009), after organizations have understood the elements of knowledge sharing and collaboration among workers, then suitable management practices can be applied to encourage such behaviour and thus improve productivity, innovation skills and overall organizational competitiveness. These key elements, identified by Paroutis and Saleh (2009), are: history, result expectations, perceived organizational/management support and trust. *History* means in this context "the old and established way of doing things", which appears to be one of the key obstacles to knowledge sharing and collaboration by using Web 2.0 technologies. Further, workers who perceive and gain positive *outcomes* from using the technologies are the ones contributing actively, whereas those who are not convinced about the benefits, sceptical about them, or perceive that the costs of using these tools are bigger than the benefits, are those who refrain to use them. In addition, many elements of *managerial support* were highlighted in the study of Paroutis and Saleh (op.cit.), such as creating awareness about the tools, endorsing their usage, training, and sharing the benefits to inspire adoption among the workers. Finally, workers need to *trust* the quality and accuracy of the information being shared. Based on these findings, the following recommendations were made by Paroutis and Saleh (2009) when introducing Web 2.0 technologies to the workers:

1) Top management should have an active role when introducing Web 2.0 technologies, they should share their benefits and explain how they fit into the company's knowledge management strategy, and how they could support to attain organizational objectives.
2) The necessary training of these technologies and the appropriate reward systems should be in place.
3) The management should avoid to mandate or enforce workers for knowledge sharing by using Web 2.0.
4) Rewards, like recognition, are essential for encouraging knowledge sharing. These rewards could be introducing soft rewards like compliment and recognition to encourage worker participation. E.g. recognition programs like "most active blog", "top-rated blog post" or "best wiki contribution", which are published on the intranet or internal news are effective ways to recognize workers. (Paroutis and Saleh, 2009)

Nakano et al. (2013) indicate in their study that tacit knowledge is considered as an important resource for companies in order to achieve competitive advantage, and tacit knowledge plays a significant role among workers at the shop floor. Workers use, share and develop their tacit knowledge when they are performing their daily tasks, and these processes are important facets of efficient manufacturing operations. Many shop floor environments are less structured than the shop floors of automotive manufacturers or global producers of auto components or parts. In these unstructured production environments, the processes are not fully recorded, and depends on the tacit knowledge of blue-collar workers, i.e. workers at the shop floor. In these types of unstructured environments, the workers must cope with any unusual working conditions that may come, and these unusual conditions may cause non-conformities and require modifications to the operational parameters of machines. Therefore, skilled, high-performing shop-floor workers have developed tacit knowledge to deal with unusual events quickly and to make actions that return malfunctioning machines or systems to ordinary conditions. Figure 8 illustrates an engaging environment, where workers are devoted to efficient and safe procedures, which are supported with a shared language and a mutual knowledge base, and which enhances the sharing of tacit knowledge. An engaging environment also favours knowledge dissemination in addition to the improvement of performance. (Nakano et al., 2013)

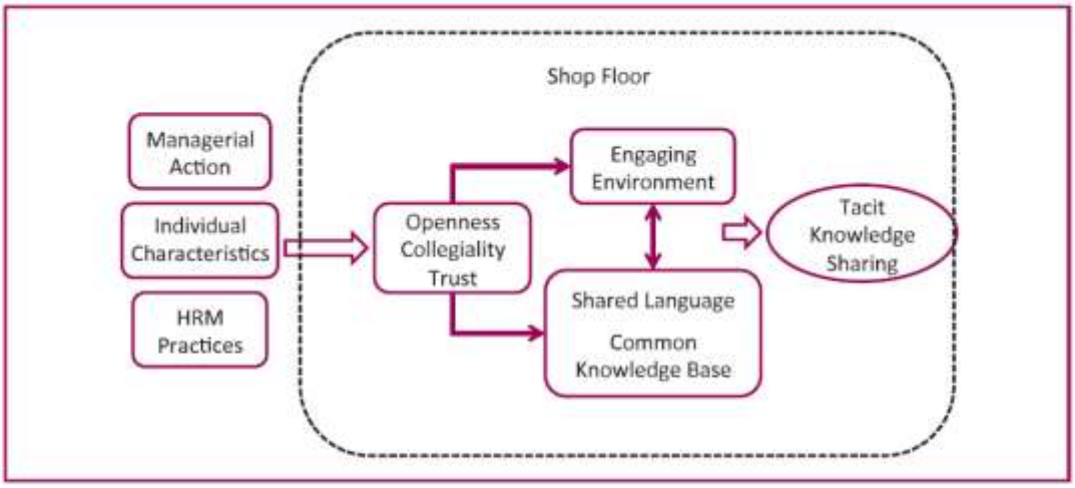


Figure 8. Environment for tacit knowledge sharing (Nakano et al., 2013, p. 302)

Overcoming the challenges related to active knowledge sharing and management holds great potential for the improvement of manufacturing work and worker satisfaction. Such a Knowledge Management System (KMS), along with all the associated complementary non-technical modifications to management and organization of work would empower workers to share their contributions openly in a communally updated pool of knowledge. Full utilization of worker-generated content and peer sharing about best practices, problem solving and ideas fuels organizational learning and even worker-driven innovation. The KMS may remove productivity bottlenecks and improve the pace and depth of on-the-job learning, while the worker feels more valued, more socially connected to the work community and better motivated – all adding to work satisfaction.

3.3 IC3 - Self-learning manufacturing workplaces

Manufacturing companies are encouraged to invest in new and more integrated monitoring and control solutions in order to optimize the production processes to facilitate quicker fault detection and reduce breakdowns during production (Orio et al., 2015). Automotive manufacturing companies are especially sensitive to production disruptions and sudden production changes, due to the multiplicity of demands that they are required to comply to. Responsiveness and resilience to production changes needs to be improved while maintaining or improving efficiency, work safety and satisfaction. This is possible by a process of continuous intelligent and self-learning optimization relying on timely product/resources/process data and diagnostics tools. By involving the shop-floor workers through proper data presentation and a user-friendly interface to the system, as well as automating production-related services, together allow much more efficient operations to evolve dynamically according to actual needs. Active monitoring and responding to problems with the utilized machinery and devices helps keep production predictable, safe and efficient. Collecting and interpreting data patterns in the manufacturing process make it possible to identify where in the manufacturing process and its services problems and bottlenecks arise and how they will be most effectively addressed, as well as assess the time that the repair and maintenance process will take.

3.3.1 Self-learning workplaces and predictive data mining

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. A self-learning workplace seeks to optimize Overall Equipment Effectiveness (OEE) by following three key performance areas (with their related metrics): availability (operating time in % of the machine scheduled time, i.e. Uptime), quality (good units produced as a % of the Total Units Planned for Production) and performance (measured by pcs./minute). However the manufacturing knowledge and information is currently scattered across a plethora of information silos without a centralized platform to connect, combine, analyse and organize the information according to the present needs of the shop-floor worker. Mastering the complexity of manufacturing information through the linking of information sources and documents requires sophisticated semantic and data mining technologies to discover the relationships between different sources of manufacturing data, allowing intelligent search and exploration. A high level of transparency needs to be maintained to make it possible to evaluate the manufacturing process and find patterns that determine the quality of the process and product from the massive amount of production data generated and analysed. A learning cycle needs to be implemented on the system level to address the known problem scenarios by combining them to successful solutions pre-emptively.

Predictive Data Mining (PDM) combines modern data mining techniques with modern time series analysis techniques. PDM is based on learning to predict new events on the basis of historical data. Learning is the process of analysing and iteratively processing the data, what can be characterized as a "trial and error" process. In other words, the forecasts are generated by the learning system based on exhaustive investigation of historical data. PDM will deal with pre-processing, data quality estimation, feature selection, prediction, and forecasting. Pre-processing should include transformation of available data into formats better suited for further processing in the forecasting and analysis system. The different phases for predictive data mining are presented in Figure 9.

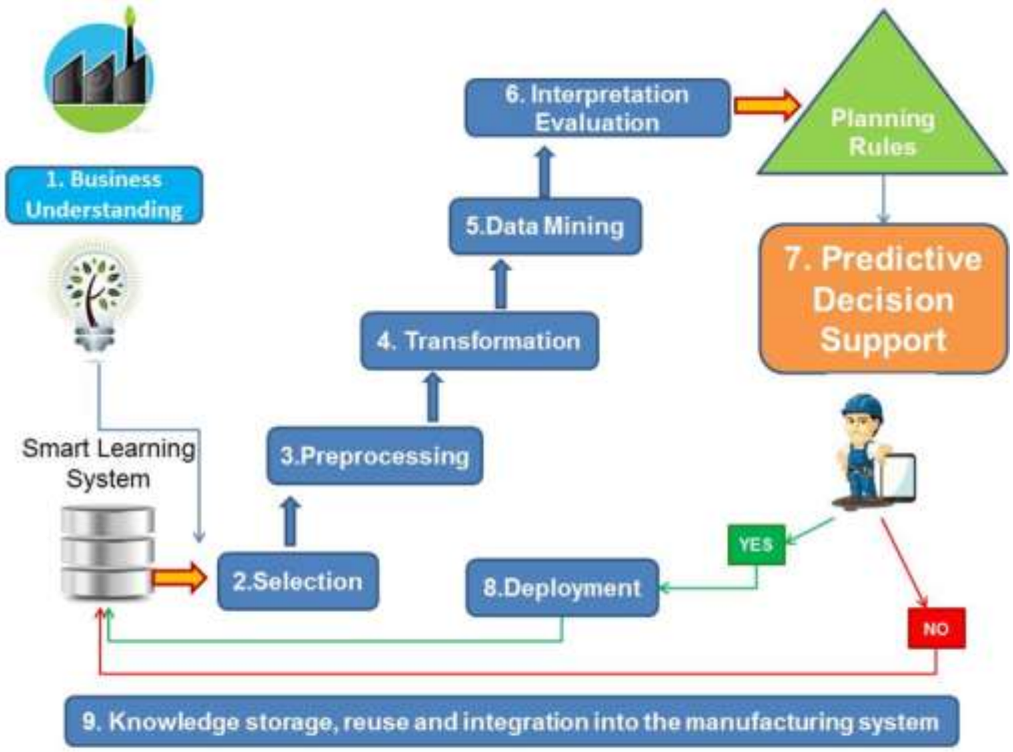


Figure 9. Steps in predictive data mining (PDM)

According to Orio et al. (2015), the key assumption is that integrating context awareness and data mining techniques with traditional and control solutions will decrease problems in maintenance, downtimes in production lines and operational costs of manufacturing, and at the same time guaranteeing a more efficient management of resources in manufacturing environment. For example PDM in maintenance work, according to Selcuk (2016), primarily involves foreseeing breakdown of the system to be maintained by detecting early signs of failure in order to make the maintenance work more proactive. Selcuk covers the latest techniques and their application areas of predictive maintenance, such as performance monitoring, vibration analysis, oil analysis, thermographic analysis, and acoustic analysis. The study also outlines some important points that should be considered for successful predictive maintenance implementation. In addition, the study reports the latest developments and future trends in predictive maintenance, such as E-maintenance, remote maintenance and management systems, tele-maintenance, IoT, and RFID.

3.3.2 Industry challenge -specific requirements, technologies and methods

IC-specific requirements:

- Predictive, pro-active decision support for workers and services
- Integration of MES, SCADA, ERP data for shop floor assistance
- Suitable visualization of context-aware information by adaptive HCI/HMI concepts
- Creation of a self-learning workplace based on predictive data analysis
- Automated, adaptive control of the services involved in the process

Vision: The overall goal of the Industrial Challenge is to create a shop floor prototype solution applied to a particular manufacturing line with a product/resources/process data integration system that will monitor a combination of process/machine parameters – offering a proactive, predictive decision support to shop floor workers. The proposed solution is based on the general OEE principle. The IC will use new technologies to monitor in live time the following three areas covered by the OEE metric: availability, quality and performance. The most recent data mining techniques will be applied to address the challenges described above, as manufacturing knowledge and information is scattered across a plethora of information silos ('walled gardens'), but central platforms to analyse, search and explore engineering and manufacturing knowledge are not available yet, and what is more – the information is not interconnected to a useful, logically organized pattern that stresses the information that is important for the worker. Today's machines gather an enormous amount of "production data", which is currently not evaluated to make manufacturing more successful (i.e., apply algorithms to learn why delays resulted and scrap was produced). Mastering the complexity of manufacturing information through the linking of information sources and documents requires applying semantic and data mining technologies for discovering relationships between different sources of manufacturing data, and allowing intelligent search and exploration. Self-educating workplaces require making transparent what patterns determine a successful production and a high product or process quality by gathering, assessing and evaluating data from the machine and descriptions of services and processes, and transferring this as knowledge to the manufacturer. Reoccurrence of problems will be prevented by storing and sorting the production data systematically and combining it with successful solutions – thereby enabling **self-learning workplaces.**

IC-specific technologies and methods:

- Cross Industry Standard Process for Data Mining (CRISP-DM), a framework for predictive data mining (PDM) in 9 steps: business understanding, selection, pre-processing, transformation, data mining and interpretation, evaluation, supplemented by KPI-based planning rules, predictive decision support (YES/NO), and deployment and knowledge storing in the KMS
- Various data mining functions (e.g. clustering, classification, association, prediction, and regression) need to be performed to derive the model
- Visual data analytics and self-learning algorithms
- Service description, composition, and management
- Suitable HCI/HMI concepts and interfaces for Decision Support Systems (DSS)

Building blocks demonstrated in industrial challenge:

Smart factory layer	Building blocks
Worker interfaces:	HMD, other wearables, desktop, machine, screen
Services:	Intelligent Dashboard, Decision Support Systems (DSS)
Technologies:	Data mining, Semantics, Visual Framework
Data:	Worker-sensors, MES/ERP/SCADA, KMS, production data

3.4 IC4 - In-situ mobile learning in production

Small and medium-sized production enterprises (SME) in the automotive value chain and networks need to comply with a serious number of specific requirements and regulations. Additionally, compared to large enterprises, the workers do not always have clearly specified roles, but rather need to perform very different tasks and share responsibilities in production. This causes the pervasive need of overall on-the-job knowledge, available at the right time in the right place. Furthermore, knowledge is subject to continuous change as work practices evolve and requirements change. The Industrial Challenge of in-situ mobile learning in production will develop and demonstrate an on-the-job learning environment for shop floor workers by using rich media through a knowledge management system, which is especially valuable for SMEs.

3.4.1 Mobile learning

So far, generic knowledge is often learnt “off-the-job” in order to qualify workers for production work, and it appears that this gap can be bridged by mobile learning in the right context (various terms are applicable for mobile learning, such as mLearning, in-situ learning, and mobile workplace-based learning) (Frohberg et al., 2009). In Figure 10, the evolution of learning models is presented, where mobile learning is considered to be the latest step in the inherent evolution (Pereira and Rodrigues, 2013). Mobile technologies, such as smart phones, tablets and most recently, digital data glasses are gathering considerable interest in the field of work-related education and learning at workplace. However, there is remarkably small amount of systematic knowledge available about how these mobile devices can be utilized effectively for competence development and learning in the workplace. There exists couple of exceptions, such as the first empirical studies (Pachler et al., 2011) and theoretical and conceptual discussions (Pimmer et al., 2010), as well as Pimmer and Pachler (2014), who show the limitations of existing mobile learning concepts and stress the “learning in the right context” by mobile devices.

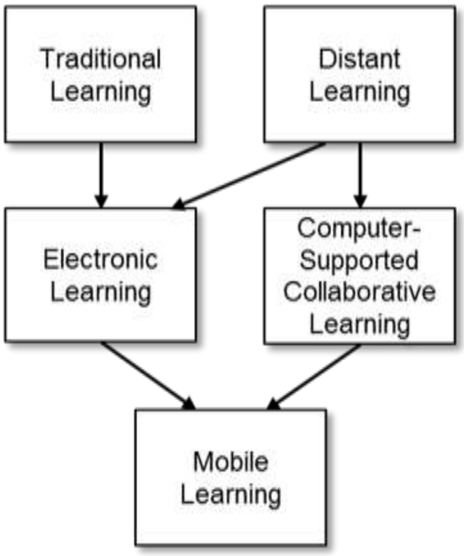


Figure 10. Evolution of learning methods (Pereira and Rodrigues, 2013, p. 27)

Wigley (2013) report of the key challenges and benefits of mobile learning in a case study at Jaguar Land Rover, as well as considerations for any business going mobile. The key points in Wigley's study when looking for deploying mobile learning are:

- Mobile learning is not a replacement for any other form of learning currently deployed: when used correctly, mobile can deliver supportive, on demand and in-situ learning, by directly assisting learners in their job roles
- Native applications, i.e. applications designed specifically for mobile, have huge benefits over web-based access from a mobile device. E.g., if a worker is in a country which has limited internet access, using native applications means that an item will only have to be downloaded once, and can then be accessed when offline. Other benefits include user experience designed for the device, without the compatibility and content limitations of a browser-based offering
- The content should be considered carefully. It should be deployed in a way that compliments the device, such as short form, bite size learning. In addition, the interactive nature of mobile devices enables engaging the user in a different way, which should be considered as part of any mobile learning strategy.

Solid research work about mobile or in-situ learning in production does not exist, and the main challenge in advancing the state-of-the-art is to evaluate effective measures of in-situ mobile learning on the shop-floor solidly. According to Ellison (2007), from the pedagogical perspective, learner-centered creation and sharing of multimedia content is promising, as context-specific, multimodal and multilingual materials can be used as refreshers (e.g., maintenance instructions, safety regulations) or as instructions for e.g. new workers and trainees. Additionally, mobile phone -based decision-making and problem-solving support promote learning and sense-making to decrease the uncertainty and increase the self-confidence of learners. Scenarios including augmented reality are another form of just-in-time mobile learning. Although, developments, such as digital data glasses seem to be promising, quite a little is known about how this technology can be connected to work-based training. Congruent findings indicate that when using a social network site relates to psychological well-being and supports in maintaining relations when people move throughout offline communities (Ellison et al., 2007).

Workers need context-aware learning in real-life situations ("in-situ“, pervasive learning) for continued education and training. The establishment of pervasive learning environments has to be based on a effective mixture of inter-connected sets of learning objects, data-streams, databases visualization devices (e.g., digital data glasses), and relevant HCI concepts. Peer-generated content will be crucial to sharing best practices and implicit knowledge in specific tasks. Since in-situ learning is new to these production environments, the challenge includes finding the optimal way to utilize contextual and real-time machine-generated data, and to design and deliver the learning service so that it is effective, efficient and widely accepted.

3.4.2 Industry challenge -specific requirements, technologies and methods

IC-specific requirements:

- Unlock the potential of mobile learning for work-based training in the right time and right place, directly in the situation and work context, i.e. in situ
- Contextual learning especially for younger workers, based on previously prepared learning material with experienced staff
- Learning content and interaction models taking worker roles, experience and gender aspects and multilingual learning system into account
- Combining multiple media with peer- and machine-authored content with on-the-work training and education, and delivering context-aware learning

Vision: The blending of learning and work environments for training (e.g. Digital Graffiti concepts based on leaving "digital Augmented Reality notes/instructions on machines“) provides a powerful method for continued education and training in a Smart Factory. The applied research of in-situ learning for production workers will be investigated with the industry partners. Since this is a new strategy, procedures or best practices for the design and distribution of in-situ learning experiences in SMEs have yet to be established and transferred. First experiences with such mobile pervasive learning systems in the large enterprise SCA will be transferred to SMEs in order to adapt, adopt and improve the relevant building blocks for SME-specific requirements. Highly skilled workers may be equipped with a full range of social-media and

AR-technologies for a week (including tablets and AR digital glasses) to generate specific, useful and high quality multimedia content to transfer implicit knowledge on a specific task successfully, while conducting it in real-life settings. Thinking aloud about what the worker does and why will generate a new atmosphere for low-skilled workers to learn from this content in the knowledge management platform. Furthermore, the learning content will be combined with real-time information from the machine (e.g., from a temperature sensor) to create a groundbreaking new learning experience. Hence, advancements over the state of the art include not only the way of content generation, but also the nature of learning content, which is a mixed-format content (not just mixing text with audio/video/social media, but also data from a machine and sensors).

Industrial challenge -specific technologies and methods:

- Mobile Cloud Computing and context-aware Content Management System (CMS) for multimedia (AR content, 3D multimedia, real-time sensor data, text, video, sound)
- Co-creation with shop-floor workers and HCI/HMI concepts for mobile devices (e.g. rugged tablets)
- (Semi-)automatized semantic annotations for intelligent information search and storage
- Security- and privacy-aware elements
- Learning psychology

Building blocks demonstrated in industrial challenge:

Smart factory layer	Building blocks
Worker interfaces:	HMD, other wearables, desktop, machine, screen
Services:	Intelligent Dashboard, workplace learning support
Technologies:	Semantics, Visual Framework
Data:	Worker-sensors, MES/ERP/SCADA, KMS, production data

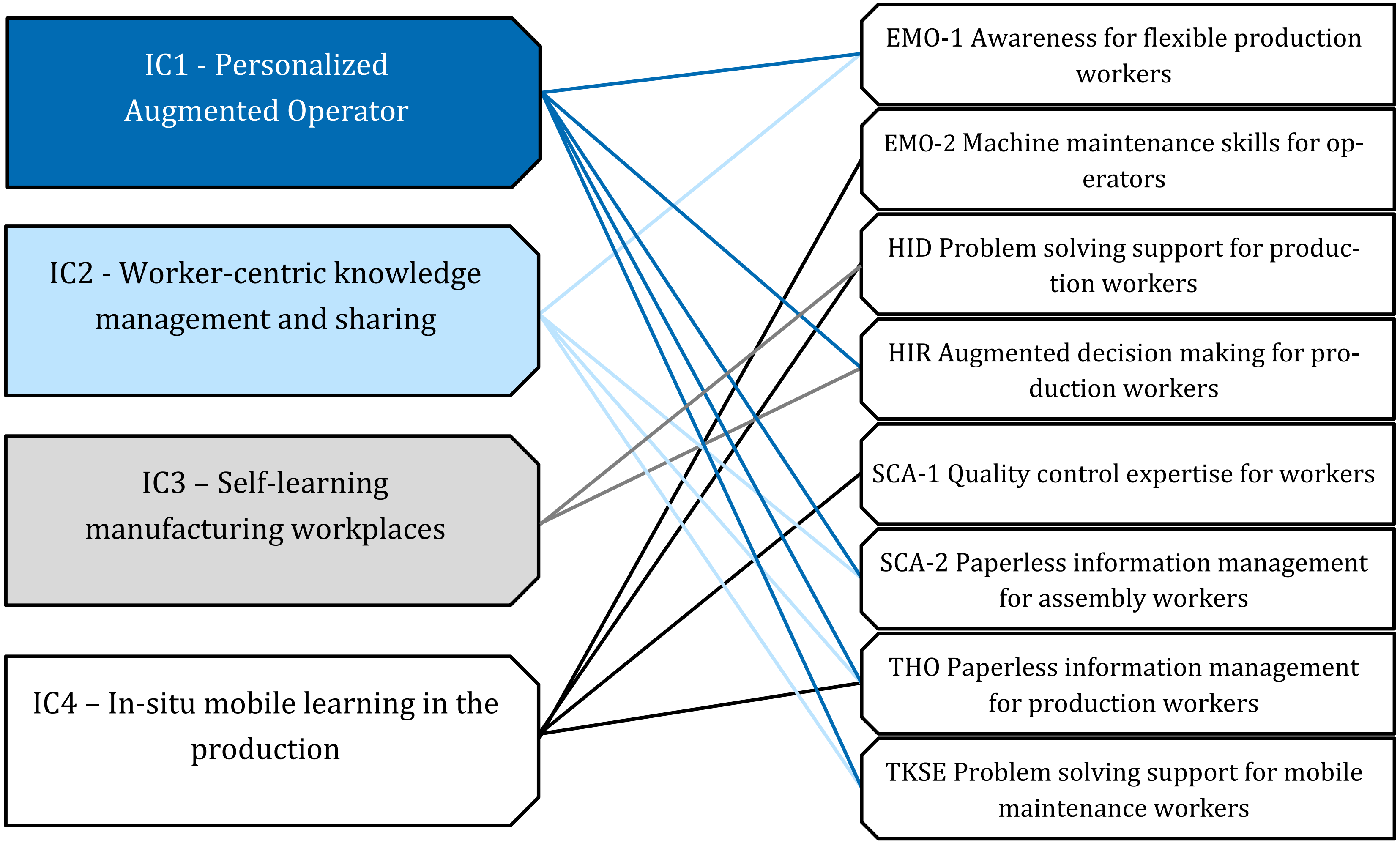
3.5 Industrial Partner -specific industrial challenges

The four Industrial Challenges will be realized in actual production environments and serve for demonstration and evaluation purposes. The application of the solutions for each IC will always be led by one industrial forerunner and several follower organizations. The prototypes will be tested at the forerunners' factories and then transferred to the factories of the followers. Taking such an approach will assure a working transfer of the developed smart factory building blocks into other manufacturing industries.

To match the Industrial Challenges to the most appropriate production environments for testing their functionalities, a matching procedure has been created between the gathered needs of the industrial partners and the IC solutions as part of the requirement gathering and analysis work. As a result of this, the challenges are substantiated and demonstrated through eight real-life use cases at the industrial partners' production environments. The graph on the following page displays the linkages between the identified use cases and Industrial Challenges. More information about the practices of workers and use cases can be seen in Deliverable (1.1) of the project.

3.5.1 IC1 – Personalized Augmented Operator

This industrial challenge addresses the core issue of providing natural interfaces that allow workers to interact and access knowledge effectively when performing their regular tasks. Solving the challenge is an essential part of enabling many of the Factories of the Future aspects and has thus multiple use cases connected to it, also within the FACTS4WORKERS industrial consortium with nearly every industrial partner involved. Hidria Rotomatika (HIR) is the forerunner here, where the use case will target enabling the production workers to utilize big data analytics fuelled by automated electronic measurements to make decisions more effectively when calibrating production equipment. Better access to information and analytics allow cutting production times while increasing product quality and reducing waste due to making better-informed decisions and detecting patterns and trends in product deviations. For the worker, being able to benefit fully from information generated by machines and previous decisions reduces frustration and helps retain a productive flow of work.


IC1 - Personalized Augmented Operator
IC2 - Worker-centric knowledge management and sharing
IC3 – Self-learning manufacturing workplaces
IC4 – In-situ mobile learning in the production
EMO-1 Awareness for flexible production workers
EMO-2 Machine maintenance skills for operators
HID Problem solving support for production workers
HIR Augmented decision making for production workers
SCA-1 Quality control expertise for workers
SCA-2 Paperless information management for assembly workers
THO Paperless information management for production workers
TKSE Problem solving support for mobile maintenance workers

3.5.2 IC2 – Worker-centric rich-media knowledge sharing and management

Another core issue concerning most FACTS4WORKERS solutions at industrial partners is to improve worker-centric knowledge sharing and management. This implies updating the tools and processes at the workers' disposal to enable peer sharing of task-specific expertise as well as partially automated logging of relevant data. The improved ability to benefit from other users' experiences and solutions adds to daily efficiency in task completion and reduces frustration of "reinventing the wheel" at every turn. The issue is exacerbated in the case of highly mobile workers, such as maintenance employees or mobile people with multiple roles in the manufacturing process, for whom it is important that the information they require can be provided anywhere and at any time. The current procedures often rely on slow, asynchronous information exchange via formal paper documentation, which is viewed as monotonous and of secondary importance. Replacing paper-based and handwritten documentation with real- or near real-time digital knowledge sharing will greatly reduce the threshold to provide accurate and timely information.

Digital knowledge sharing could be potentially realised by implementing a mobile knowledge management platform with the maintenance worker (as a mobile knowledge worker) at the centre of attention. At some of their more advanced worksites, TKSE has already introduced, as one of few manufacturing enterprises, a knowledge management system called 'Wissensspeicher' to gather experiences and lessons learned from and for workers at the machine and link them within a database setting a high value on user acceptance. This platform not only allows a long-lasting preservation of knowledge, but facilitates job training and improves intra-organisational knowledge transfer among skilled workers in steel manufacturing. Utilizing and building on these experiences, FACTS4WORKERS will further implement advanced knowledge management systems to TKSE's other operations, as well as to the unique conditions at other industrial partners' (THO, SCA and EMO) worksites. Through these solution elements, the maintenance engineers will become *smart workers*. With this form of knowledge work, communication between colleagues can be increased, experience and knowledge can be exchanged easily, and for instance fault elimination processes can be made more efficient and more satisfactory. These improvements will greatly reduce information asymmetries detrimental to work satisfaction and performance, and help to maintain a productive flow of operations.

Considering IT capabilities and human resources know-how, the system can be elevated to a European best practice in Internet of Things/Everything enhanced worker-centric knowledge management. Further use cases involve switching to paperless information management and improving the control on flexible production systems geared to producing small series of customized products.

3.5.3 IC3 – Self-learning manufacturing workplaces

With the implementation of advanced IT solutions, Internet of Things (IoT) –technologies and sufficient knowledge management procedures, new possibilities for leveraging the manufacturing knowledge arise. One such concrete advance is the creation of a self-learning manufacturing workplace. Utilizing detailed and consistent data from manufacturing operations, enterprises are able to implement e.g. predictive maintenance and machine-assisted decision making for calibrations that allow reducing unplanned process disruptions and maintaining a smooth workflow. The forerunner in this industrial challenge is Hidria Technology Center (HID), where disparate data sources are connected to realize novel decision supporting tools that enable continuous optimization of the manufacturing process.

Without advanced data mining and analytics to support it, optimization and adjustments are left to discretionary, manual changes by the personnel who often do not have access to sufficient information. Thus, implementing the FACTS4WORKERS solution will add to the ability of the workplace to adapt to changing situations dynamically and to the workers' ability to keep the workplace in planned, optimal operation even when accounting for the numerous potential faults that may occur over time.

3.5.4 IC4 - In-situ mobile learning in production

Modern working environments impose increasing demands on the flexibility and skills of workers. High-skilled manufacturing work implies continuous lifelong learning on part of the operators and especially so in manufacturing complex, high-quality products and components, such as in the case of Schaeffler AG (SCA), which is a forerunner in this industrial challenge.

Continuous competence development requires context-aware learning in real-life situations backed by access to relevant, up-to-date information and tacit knowledge. Furthermore, such capabilities need to be provided through a mobile interface compliant with the demands of factory work in order not to disturb production. First experiences with such mobile pervasive learning systems in the large enterprise SCA will be transferred to SMEs in order to adapt, adopt and improve the relevant building blocks for SME-specific requirements. Beyond training new workforce by enabling them to benefit from the experience of experienced workers, the learning platform also allows the transfer and rapid dissemination of best practices at work as they are discovered. This will reduce the perceived stress of the workforce in accommodating to changing regulations and requirements while also challenging them to improve their professional competence continuously. For SMEs, such mobile learning allows cost-efficient and rapid training of young employees, which will increase the possibility to recruit new workers flexibly to cope with increasing demand for their products.

4 Emergent themes and trends in manufacturing

The purpose of this chapter is to present the emergent themes and trends in manufacturing that have an effect on the future significance and new emphasis on the discussed Industrial Challenges. The aim is also to assure that our solution approaches in the project will correspond with the future trends in manufacturing.

There are recent studies discussing the emergent themes and trends affecting the industrial systems, such as UNIDO report (2013), which describes on the one hand the global "megatrends" affecting all the industrial systems, and on the other hand the main enablers of future manufacturing competitiveness. These megatrends and enablers are highlighted in the following table.

Global "Megatrends"	Enablers of future manufacturing competitiveness
Globalization	Distributed manufacturing
Sustainability	Rapidly responsive manufacturing
Demographics	Complex manufacturing
Urbanization	Customized manufacturing
Threats to global stability	Human-centered manufacturing
Accelerating product life cycles	Sustainable manufacturing
Changing consumer habits	Innovation-receptive manufacturing
External industrial policy trends	

The megatrends have implications on enablers of future competitiveness factors in manufacturing, and on the other hand, the enabling manufacturing approaches are interrelated with each other to cope with the challenges caused by the megatrends. UNIDO report also describes emerging science and technological developments such as photonics, bio- and nanotechnologies, additive manufacturing, micro-technologies etc., but one of the main implications here was that for coping with the megatrends like e.g. different elements of sustainability, more specifically social sustainability, there should be environmentally- and worker-friendly factories, which raises the importance of "human-centred approach", emphasizing people's role as innovators and decision-makers, and seeing technology as an enabler of productive human work.

Taking into account these trends enabling future manufacturing competitiveness, we can say that it is essential to put aspects like collaboration, knowledge, creativity and competence development in center. Thus, in this case, it is essential to describe also the non-technical solutions related to e.g. organizational and management adaptations that are necessary for taking full advantage of technological solutions for industrial challenges. The theoretical and best practice -based considerations are discussed from the following three perspectives, which can be seen as crossing over many of the above-mentioned trends and future competitiveness enablers:

1) Organizational aspects and learning
2) Collaborative social working environment in manufacturing
3) Empowerment of sociotechnical solutions for industrial challenges

4.1 Organizational aspects and learning

Developing a manufacturing organization from the viewpoint of knowledge management, for example improving knowledge sharing and enabling effective information and knowledge utilization through novel technical tools affects also the work practices and changes many non-technical elements of working. There are a lot of existing theoretical studies on enhancing knowledge processes such as knowledge acquisition, sharing, and storage within and between organizations, but only few extensive empirical examples are presented in the literature, mainly because the solutions are always context-depended and include elements from several disciplines and organizational units.

The changes by introducing knowledge work tools on the manufacturing shop floor can affect for example the organizational hierarchies and distribution of decision-making, leadership practices, collaboration practices, work models, incentives, need for personnel training etc. In the FACTS4WORKERS project, we have identified three main viewpoints for analysing the integration of manufacturing work and knowledge work:

1) Technological and IT-related changes
2) Organizational practices (especially HR/KM) related changes
3) Production model and product knowledge utilization related changes

Separating knowledge work and production work has a long-standing tradition in the academic literature. In practice, however, the separation of these concepts is increasingly difficult due to the integration of knowledge work elements into manufacturing. The need of management and organizational support for knowledge work requires a different approach from traditional production work, since knowledge work is highly dependent on the level of competence of the workers. Changing the organizational processes and management practices accordingly is an open challenge (see Lampela et al, 2015; Hannola et al., 2015).

The nature of future of work has been discussed extensively in different domains, and as a generalization, the global trends commonly identified are: growing knowledge intensity, increasing virtuality of organizations, need for openness and networking, technological convergence, growing complexity, and need for sustainability. All these trends affect the content, environment and processes related to work, and lead to the need of increasing flexibility.

Organizational researchers widely agree that organizations of the future are increasingly virtual and project-based, and physical structures lose their meaning. Global distribution of operations, due to the advances in information and communication technologies, work can be done anyplace and anytime (Khallash and Kruse, 2012). From the point of view of individual workers this enables freedom and flexibility, but creates also challenges to work-life balance, as the expectations of being available also change (Lampela and Papinniemi, 2013).

Considering the manufacturing field or production work, especially the effects of technological change and convergence are often seen as most significant. According to Taisch et al. (2012), the implementation of the IoT will lead the ICT solutions at the shop floor in the next decade. Operators, machines, robots, assembly lines, and items at the shop floor level will operate in a strongly connected, distributed and autonomous network. Seamless exchange of information and easy to plug-and-work devices will be dominated from the ICT perspective in the shop floor. (Taisch et al., 2012)

In addition, it should be noted that the discussion of smart factories and smart products has been expanded to smart production ecosystems, or "system of systems" (Porter and Heppelmann, 2014). In the ecosystem, from the engineering point of view, the product lines of factories and product lines of goods need to be integrated. An ecosystem is a collaborative network of stakeholders with various roles in the value chain. This type of approach means that also all the stakeholders, e.g. operators should see the "big picture" as well as the configuration activities and technologies on both factory and product levels (e.g. Dhungana et al., 2015).

It is assumed that smart, connected products and factories and the ICT solutions enabling them will transform manufacturing industries and their value chain in a significant manner. This also puts pressure on reconsidering the organizational structures with new ways of collaboration. Porter and Heppelmann (2014) present a new generic organizational structure in which there are new structural units for focusing on data management, ongoing product development and management of customer success (Figure 11).

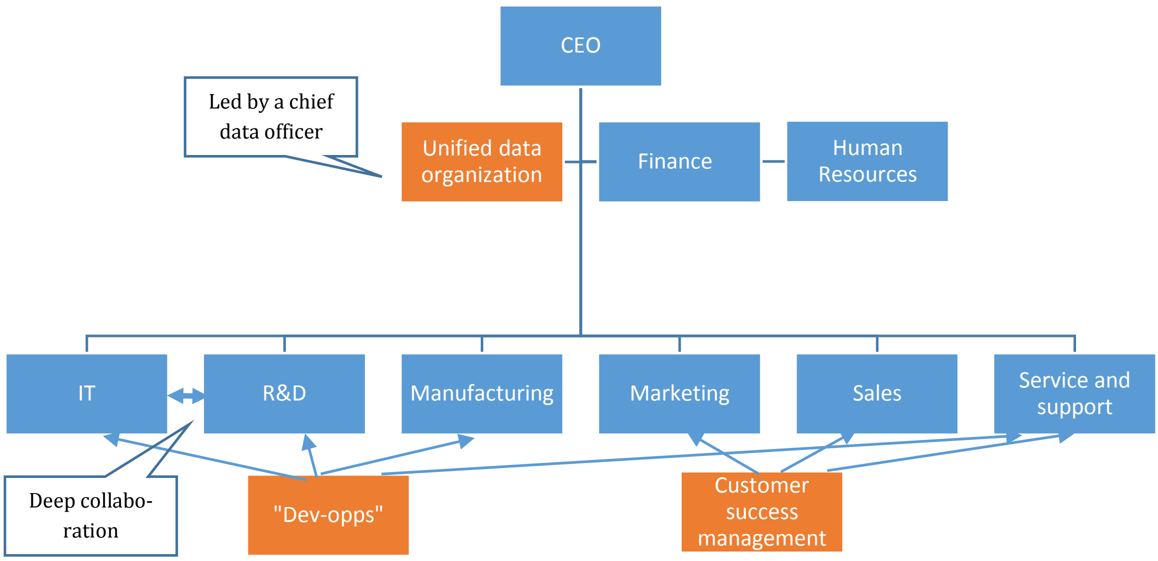


Figure 11. A new organizational structure (Porter and Heppelmann, 2015)

As the reconfiguration of organizational processes calls for novel ways of collaboration, the next section focuses on collaborative trends and related connections.

4.2 Collaborative social working environment in manufacturing

The operating environment has become open and networked, and this has also changed the processes and tools of collaboration. The importance of social networks is growing as hierarchical organization structures are evolving to respond better to this development. The decentralization of organizations is also reflected on technical solutions, particularly ICT. The rapid changes of available technology require flexibility in the ICT architectures of organizations, and also in the policies of how the tools are used. For example the adoption of social media tools has had profound effects on collaborative practices in organizations. (Lampela et al, 2011)

In relation to the FoF SO-PC-PRO-project, Kannengiesser et al. (2015) have used a "meta-process" approach (see Figure 12) to support workers' collaborative process improvement with the help of 1) social software, 2) formal workflow for process improvements and 3) intuitive representation of the core process. A tool developed in the project, called *SURF* (*S*ubject-oriented s*U*ggestions for *R*e-design of *F*actory workplaces) aims to help workers in reporting, discussing and finding solutions to problems in a collaborative manner. The tool has been tested in the goods entry area of a large Italian manufacturer of industrial cleaning machines. This kind of approach, if implemented with a user-centric, easy-to-adapt ICT tools, is expected to tackle the challenge of lack of transparency in decision-making of improvement suggestions in the manufacturing environment. It should support the participation possibilities of shop-floor workers in general for continuous improvement of operations and workplaces.

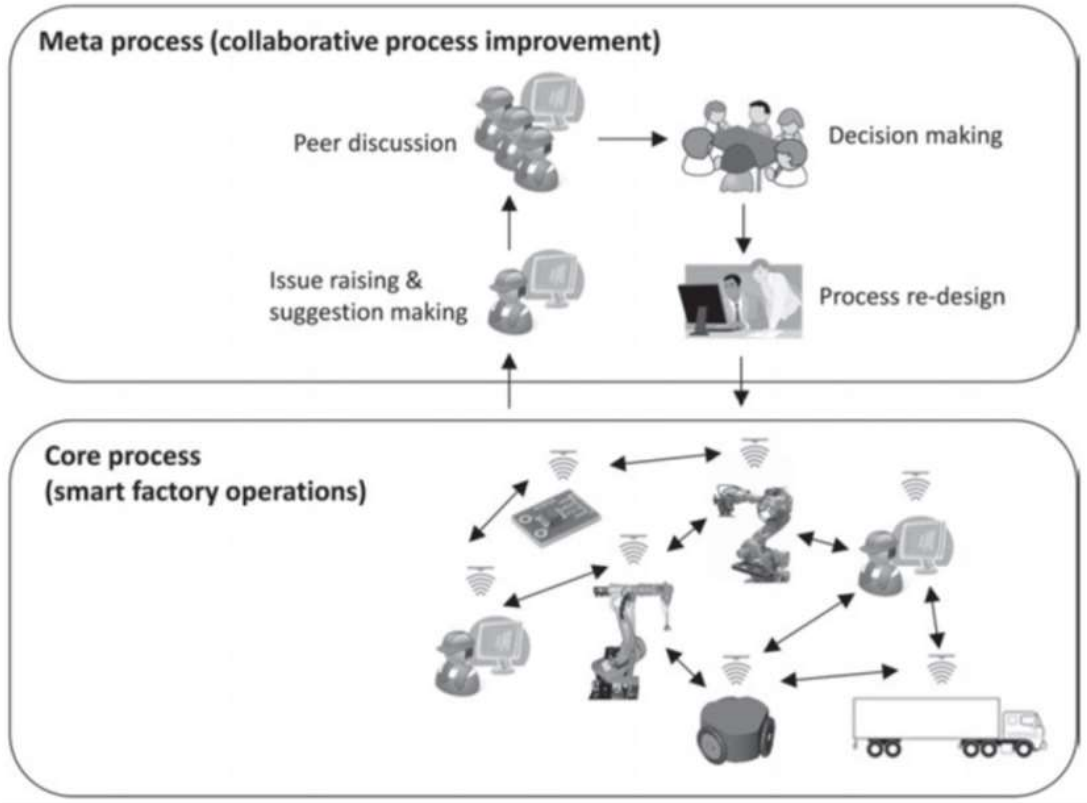


Figure 12. A metaprocess for collaborative improvement of core processes (Kannengiesser et al., 2015, p. 241)

As FACTS4WORKERS is underpinned by a clear human-centric approach (see e.g. Zuehlke, 2010): usability, user experience and technology acceptance are of utmost interest. To achieve high acceptance by the worker, the developed applications must comply with the general current quality criteria, guidelines and standards for web-based applications, regarding their design and usability and among other the following aspects: 1) Usability und user experience, 2) Interface aspects, and 3) Social aspects (see Figure 13). The social aspects play a significant role in adopting the new tools supporting the collaboration required by the smart factory environment.

Usability and User Experience	Interface aspects	Social aspects
• Ease of use • Usefulness • Learnability • Speed • Accuracy • User task performance • User error rate • Subjective user satisfaction	• Interface styles • Information organization • Visualization • Navigation	• Privacy, trust, safety and security • Human interaction • Empowerment • User control • Personalization • Undisruptiveness/ Convenience • Collaboration

Figure 13. Aspects to cover to achieve high acceptance of new applications by workers

4.3 Empowering workers with socio-technical solutions for industrial challenges

The presented models, frameworks, methods and tools originated from existing studies and projects, and when applied in other organizations, will be considered as partial non-technical solutions complementing the ICT solutions related to each described industrial challenge:

IC1: Personalized augmented operator
IC2: Worked-centric rich-media knowledge sharing and management
IC3: Self-learning manufacturing workplaces
IC4: In-situ mobile learning in the production

It is assumed that when solving an Industrial Challenge, process, organizational and management adaptations will be required to take full advantage of technical solutions and opportunities. These adaptations will also ensure worker empowerment through enabling more independency, flexibility and support in decision-making or problem-solving situations.

As an example of connecting use cases of Industrial Partners in the FACTS4WORKERS project with potential solutions to industrial challenges also from the non-technical point of view, we discuss EMO's use cases briefly below. These cases are related to Awareness of flexible production workers and Machine maintenance skills of operators.

The first one, "Awareness of flexible workers", is linked to IC1 and IC2, and in addition to mobile ICT solutions. The non-technical solutions are related to strengthening the networking and interconnection capabilities. This would help in finding the solutions for the problems raised in this use case, e.g. lack or insufficient information about the current work status or about the parts to be produced. In addition to direct effects on production, developing these capabilities by e.g. following the collaborative process improvement approach suggested by Kannengiesser et al. (2015) could also increase the innovation capabilities within the production staff and thus decrease frustration and increase work satisfaction.

The second one, “Machine maintenance skills of operators”, means on a non-technical level that mobile solutions for maintenance work would also need to be complemented with personalized learning experience related to the work. Especially in those maintenance activities which are not done very frequently, the knowledge may often be individual and tacit. Making this more explicit would mean that knowledge management systems should include clear specific instructions and guidelines for the task. Another important measure nowadays is safety, which means that in the learning interface the criticality of each task should also be assessed systematically from the viewpoint of safety and security, and the guidelines should be made as clear as possible to avoid any incidents. Making all these learning solutions to really happen and especially their adaptation by the workers may also require reconsiderations of competence development processes at the organizational level.

Similarly, the use cases of other partners; HID, HIR, SCA, THO and TKSE, can be connected to one or more industrial challenges (as described in Chapter 3.5), in which non-technical solutions complement technology-based solutions.

The significance of organizational solutions and innovations in addition to technological ones has also been recognized and analyzed from the point of view of emergent manufacturing themes in the earlier mentioned UNIDO report (2013) by the University of Cambridge. As previously discussed, the study also separates the enablers of future manufacturing competitiveness into the following areas of manufacturing:

- Distributed
- Rapidly responsive
- Complex
- Customized
- Human-centered
- Sustainable, and
- Innovation-receptive manufacturing

For example, in a distributed manufacturing environment the partial non-technical solutions may be related to the approach of grid manufacturing, and in human-centred manufacturing to improved collaboration between robots and humans (UNIDO, 2013). The above-mentioned general trends and future enablers of manufacturing have potential effects on ICs and related solutions in the FACTS4WORKERS project contexts, and thus analyzing their potential impact in more detail would be one of the areas for further examinations in the refined Industrial Challenges reports to be produced during the project.

5 Discussion and conclusions

5.1 Key learning and recommendations

This section highlights some of the key learning and recommendations about the Industrial Challenges, production models and methods in manufacturing. These aspects are based on the related literature, previous experiences and accumulated knowledge during the project in manufacturing companies. These recommendations serve as a starting point for further analysis of the Industrial Challenges and supporting tools to overcome the challenges within the project.

There are several specific **requirements** that should be taken into account when **adopting new ICT tools on the shop floor** (compared to e.g. an office environment). These are:

1) Tools need to be more open for empowering and motivating the workers easily, actively and spontaneously contribute know-how to an always up-to-date knowledge pool
2) Interaction schemes need to be even more simple and intuitive, e.g. touch or gesture interaction instead of typing
3) Extreme conditions need to take into account in production environments, e.g. extreme heat or noise
4) Tools need to be much more robust, e.g. "rugged devices"
5) Safety needs to be guaranteed throughout whole production processes
6) Data and know-how security must be assured
7) Workers privacy must be guaranteed
8) Usability, user experience and technology acceptance by the workers on the shop floor need to be taken into account

As Lacerda et al., (2015) stated, the waste of **human talent** and potential can result in lost improvement opportunities, while the lean philosophy believes that every human is a thinker and can result with positive outcomes. Yew et al. (2016) emphasise the role of skilled shop-floor-workers, because they are those who ensure that product specifications are met, deadlines are fulfilled, and they keep the machines running. Especially, in addition to **explicit information**, the utilization of **tacit knowledge** of workers should be encouraged. These will be supported in the FACTS4WORKERS e.g. by developing new F4W solutions, where workers can also document information and their personal know-how and experiences about the problem and solution recommendations. This will support team leaders, line operators or maintenance workers in the shop floor to resolve problems at-hand and in the future.

Workers movement at the shop floor does not add value to the product (Lacerda et al. 2015). This is often caused by placing the tools and components within the work station or is related to ergonomic aspects that requires bigger efforts from the workers than necessary. In addition, e.g. the movement of a maintenance worker is often related to finding the right persons with the knowledge to solve the problems. The reduction of the worker movement will be supported in the FACTS4WORKERS e.g. by developing ICT tools, which help workers to find information and also tacit knowledge from their own work place (e.g. tablets) without wondering around the shop floor.

In current production, increasing **social interaction** among team members on the shop-floor is a topic, which is not yet supported by information technology. To stimulate interaction across workers, teams or production sites, new modes of using technology will be required. There are still no scientific cases studies of social media reported to assist manufacturing collaboration in the production facility. The transformation of social technologies to a production environment is expected to be one of the advancements of FACTS4WORKERS.

As a consequence of the growing responsibility areas of managers, they tend to spend less time on the shop floor. This should be compensated for by **a new structure of the daily routines** of managers and the introduction of shift meetings, which take place e.g. on the shop floor and not in closed meeting rooms. By those strategies the leading personnel should be recognized at the shop floor, which enhances motivation of the workforce and facilitates the problem solving process. In general, the introduction of new ICT tools enable new daily routines, as they may overtake some of the previous ones.

Jidoka is the strategy of understanding and eliminating the **root cause of all defects** to drive improvement, which includes four principles: (1) detect the abnormality, (2) stop the process, (3) fix the immediate condition, and (4) investigate the root cause. These strategies are implemented using an ever-evolving variety of methods and tools, such as visual management or value stream mapping. Eliminating defects or breakdowns in production has always been a management goal, but hidden defects are nearly always overlooked. Hidden problems are the ones that eventually might become serious threats. If problems can be **visualized**, it is easier to find solutions to them. This will be supported in the FACTS4WORKERS by developing ICT tools (e.g. augmented reality tools), which support the visualization of the problem and the solution approach for shop floor workers. Through the tools, workers can 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. This will support the identification and understanding of the root cause of the problem or defect. In case of hidden defects, a systematic Root Cause Analysis is recommended.

Overcoming the challenges related to active knowledge sharing and management holds great potential for improvement of manufacturing work and worker satisfaction. In addition of introducing new means and ICT tools, it is essential for organizations to recognize what **motivates workers to share their knowledge** and what **prevents them** for knowledge sharing. Following recommendations can be made, based on the study of Paroutis and Saleh (2009):

1) Top management should have an active role when introducing ICT tools, they should share the benefits and explain how they are fitting into the knowledge management strategy of the company, and how they could support to attain organizational objectives
2) The necessary training of the ICT tools and the appropriate reward systems should be in place
3) The management should avoid to mandate or enforce workers for knowledge sharing by using new tools
4) Rewards, like recognition, are essential for encouraging knowledge sharing. These rewards could be introducing soft rewards like compliment and recognition to encourage worker participation

ICT tools along with all the associated new work practices and organization of work would empower workers to openly share their contributions to a communally updated pool of knowledge. Full utilization of worker generated content and peer sharing about best practices, problem solving and ideas stimulates organizational learning and even worker-driven innovations.

5.2 Summary

The ultimate goal of the H2020 project "FACTS4WORKERS – Worker-Centric Workplaces in Smart Factories" (FoF 2014/636778) is to develop and demonstrate sociotechnical solutions that support smarter work, i.e. providing employees with the information they need to perform their day-to-day work at the right time and in an appropriate manner in order to improve decision making, support the search for problem solutions and strengthen employees' position on the factory floor.

This deliverable (D1.3) introduced the key production models and related methods in general that manufacturing companies are applying. The four Industrial Challenges were described that are defined at the factories of the industrial partners on the project. The industrial challenges presented in this deliverable were as following: 1) Personalized augmented operator, 2) Worker-centric rich-media knowledge sharing/management, 3) Self-learning manufacturing workplaces, and 4) In-situ mobile learning in the production. The Industrial Challenges are intended for testing and prototyping the smart factory building blocks at the forerunners' factories and then transferred to the factories of followers.

The deliverable also matched the four Industrial Challenges into Industry Specific use cases. In addition, emergent themes and trends in manufacturing were described in order to assure that our solution approaches in the project will correspond with the future trends. Finally, the key learning and recommendations were provided. This is the first version of the detailed Industrial Challenges and the deliverable will be refined after each year of the FACTS4WORKERS project as the Industrial Challenges evolve.

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About the project

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
Hidira 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:

virtual vehicle

VIRTUAL VEHICLE Research Center
Inffeldgasse 21A
8010 Graz, AUSTRIA

Tel.: +43-316-873-9077
Fax: +43-316-873-9002
E-Mail: facts4workers@v2c2.at

FOLLOW US AT:

FACTS4WORKERS
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Detailed and Refined Industrial Challenges, version I

The ultimate goal of the H2020 project "FACTS4WORKERS – Worker-Centric Work-places in Smart Factories" (FoF 2014/636778) is to develop and demonstrate sociotechnical solutions that support smarter work, i.e. providing employees with the information they need to perform their day-to-day work at the right time and in an appropriate manner in order to improve decision making, support the search for problem solutions and strengthen employees' position on the factory floor.

This deliverable (D1.3) introduces the key production models in general and the related methods that manufacturing companies are applying. Each of the production methods has specific challenges and recommendations related to improving the productivity of the workplace.

This deliverable reports on four Industrial Challenges (IC) chosen from Industrial Partners of FACTS4WORKERS, which are also generalizable to other companies in the manufacturing industry. These four Industrial Challenges are 1): Personalized augmented operator, 2) Worked-centric rich-media knowledge sharing/management, 3) Self-learning manufacturing workplaces, and 4) In-situ mobile learning in the production. The industrial challenges are intended for testing and prototyping the smart factory building blocks at the forerunners' factories and then transferred to the factories for followers.

The objective of this deliverable is also to match the Industrial Challenges with Industry Specific use cases. In addition, emergent themes and trends in manufacturing are described in order to assure that our solution approaches in the project will correspond with the future trends. This is the first version of the detailed Industrial Challenges and the deliverable will be refined after each year of the FACTS4WORKERS project as the Industrial Challenges evolve.