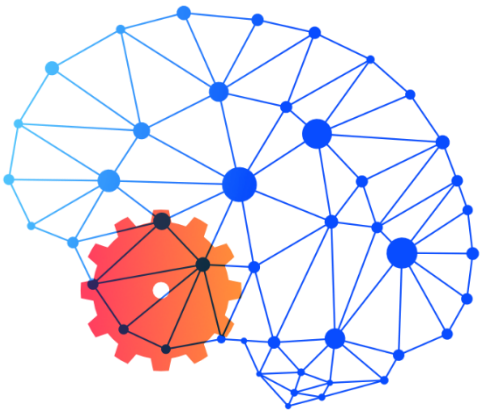

capri

Cognitive Automation Platform for European PRocess Industry digital transformation

Deliverable

D2.3 Digital Transformation Methodology for process industries definition

Deliverable Lead: POLIMI

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EXECUTIVE SUMMARY / ABSTRACT SCOPE

The main scope of the deliverable is giving a complete overview of the two tools utilized inside the digital transformation methodology presented by Politecnico di Milano and to show the validation of them for process industry. Moreover, the first results collected from use cases inside CAPRI's T2.3 have been reported.

The deliverable is organized as follows. Chapter 1 gives an introduction to the context and to the T2.3 activities done, an introduction about the two main tools utilized by Politecnico di Milano in driving digital transformation process have been showed. Then, a specific paragraph (Chapter 2 and Chapter 3) both for Industry 4.0 Test and 6Ps Model has been written in order to give a detailed presentation about how the tools have been structured. Industry 4.0 Test aims at assessing the digital maturity of a company, 6Ps model aims at supporting company's digital transformation journey.

Furthermore, chapter 4 and chapter 5 of the document have been dedicated to present the validation of the tools and the results obtained from Industry 4.0 Test and 6Ps Model. Partners committed themselves in providing suggestions about how to adapt the Test Industry 4.0 to process industry and later, they assessed their digital maturity level filling the online test. Moreover, all use cases filled the 6Ps online survey, then, a set of interviews has been organized in order to validate answers and clarify their AS-IS situation and the desired one after CAPRI's project (TO-BE). Along both sections mentioned, radar charts have been reported with the aim of giving a more understandable view of the work.

Finally, in Chapter 6, a conclusion and a future outlook of the work have been outlined.

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I Introduction

T2.3, according to the grant agreement, is entitled "6Ps methodology for Cognitive Digital Transformation of process industry", the objective is related with study and implement a methodology to define and assess a digital transformation pathways for process industry derived from existing ones in discrete manufacturing. In order to reach the objective, POLIMI team, took in consideration the digital transformation methodology that typically internally use for **discrete manufacturing**, and, together with some CAPRI's partners, adapted the tool for **process industry** use. From all CAPRI's industries: Asphalt, Steel and Pharma have been collected useful suggestions for reaching the objective mentioned above.

The POLIMI digital transformation (DT) methodology, consists in **three main steps**, at first it is fundamental **assessing the digital maturity** of a company, in this first part it is important the internal identification of the right profile to collect all the information needed to fulfil the assessment in the most accurate way. This part turns out to be crucial not only for the evaluation of the current digital maturity level of the firm but also for the estimate of the desired digital maturity to achieve. The second step regards **setting a clear digital transformation journey**. Once both the so called AS-IS and the desired TO-BE situation have been clearly defined, the next step consists in the identification of the priorities of potential actions to undertake. Finally, it is necessary to **implement** the digital transformation journey in the right way.

POLIMI uses two main tools for supporting the first two steps of the DT methodology, **Test Industry 4.0** and **6Ps survey**, both of them are deeply explained in chapter 2 and chapter 3 of the document, moreover, their validation and results have been reported in chapter 4 and chapter 5.

In **Chapter 2**, as anticipated, the "**Test industry 4.0**" and its online questionnaire has been presented. Test Industry 4.0 is a methodology developed internally throughout a PhD work thesis; it is part of a bigger instrument named DREAMY 4.0 Assessment Tool[1] developed with the aim of addressing the digital maturity of a company analysing different business processes (e.g., Design and Engineering, Production, Supply Chain). The structure of the tool is the one of a questionnaire; around fifteen questions for each section have been proposed, they are studied looking at four dimension: Monitoring & Control, Execution, Technology and Organization. Finally, results are summarized and put in light using radar charts.

In **Chapter 3** the "***6Ps digital transformation roadmap***" and its **online survey** has been described. As Test Industry 4.0, 6Ps online survey is part of a bigger methodology for supporting digital transformation but it has a different focus, 6Ps gives a concrete idea of actions that need to be followed along a digital transformation journey. It doesn't measure the digital maturity but it put in light the **level of progress** that your company has towards digital solutions implementation. It covers six dimensions of analysis: Product, People, Process, Platform, Partnership and Performance. Each dimension provides concrete alternative related with the level of digitalization of a company, thanks to them, a company can clearly understand its AS-IS level of digital evolution and compare it with the desired one (TO-BE). Inside CAPRI, in order to better understand the impact of the initiative inside the industrial pilots, the end of the project has been set as time horizon for thinking about the desired TO-BE level of digital transformation.

As anticipated, during the first months of the project, partners provided suggestions about how to modify **Test Industry 4.0** with the aim of improving and customizing the tool for process industry. This activity has been reported in **Chapter 4** where the most significative improvements have been collected, some questions have been deleted, other have been added. Many words have been

[1] "A methodology to guide manufacturing companies towards digitalization", De Carolis et al., 2017

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customized according to a more appropriate language for process industry. E.g., bill of material (BOM) has been substituted with “list of ingredients”. In the same chapter, have been reported the results collected from the modified and validated online Test Industry 4.0 questionnaire for process industry.

Parallelly to the activity related with Test Industry 4.0, the **6Ps digital transformation journey** has been implemented, the use cases (EIFF, AMS and SID) filled the online survey and later, with an **interview**, results have been discussed and validated according to the need of process industry. The product dimension has been the most revised because moving from discrete manufacturing to process industry the product is different. About the other Ps of the survey, the test has been more eaily validated. In **chapter 5** all the outcomes have been commented and reported.

Finally, **chapter 6** has been dedicated to **conclusions** and **future outlooks**, after the activities in WP2, both online questionnaires will be re-presented along the WP5 experimentations to monitor the progress of the pilots in their DT journey.

2 The Test I4.0 and its sections

The **Test Industry 4.0** is a tool that takes shape with an online questionnaire, it has been created for enterprises that would like to evaluate their level of digitalization. The origin of this test resides in Politecnico di Milano and, as anticipated above, it has been developed inside a bigger methodology named **DREAMY** developed along a PhD path. The DREAMY methodology, like the Test Industry 4.0 aims at measuring the level of digital maturity of a company, it includes the Test Industry 4.0, the visit of the production plant, face to face interviews with dedicated department inside factory’s boundaries, analysis of results and a final roadmap definition about how to proceed. In T2.3 only the first step of DREAMY has been implemented: the Test Industry 4.0. The online survey is publicly available here https://www.testindustria4-0.com/. Thanks to it, companies can run a first self-assessment of their digital maturity.

In Italy, Test I4.0 self-assessment, thanks to its public visibility, has been filled from around one thousand companies during the last three years, companies knew the tool mainly thanks to Digital Innovation Hub network (71%). The Test has been conducted mainly by small-medium companies (72%) but even cases of big companies have been recorded. The majority of companies operate in discrete manufacturing (65%), but also companies committed with process industry (35%) filled the test, examples from glass, paper, wood, rubber, textile and steel industry have been gathered.

The main objective of Test Industry 4.0 applied in WP2 of CAPRI project is related with measuring the level of digital maturity of the three industrial pilots of the project: EIFF (asphalt), AMS (pharma) and SID (Steel). Once the digital maturity level is assessed, the second step of DT methodology will be implemented, in particular, 6Ps tool will support the transformation prompting concrete way of actions, its structure has been deeply described in chapter 3. In order to utilize effectively the Test Industry 4.0 for process industry, it has been modified from CAPRI’s partners before to be implemented, this part will be presented in Chapter 4, instead, in the following lines, Test Industry 4.0 structure has been reported.

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2.1 The Business Areas

The I4.0 Test measures the digital level of a company by measuring the digital maturity of the firm looking at eight business areas: Design & engineering, Supply chain, Production, Quality, Logistics, Maintenance, Marketing and Sales and Human Resources. Moreover, other two cross processes are taken in consideration along the test: Smart Product and Strategy.

Figure 1 - Test Industry 4.0 Business Areas

Here below a brief description of all the business areas mentioned, the questions related to each of the areas aim at discovering how the processes happen with a particular focus on digital tools utilization and on a lean way of acting.

- **Design and Engineering**: in this area the test focuses the attention for example on how the product concept is generated, if company make use of simulation tools during the concept validation phase, if the production area is involved in the product development phase. How change requests happen and how the product processing cycle is realized.
- **Production**: this area focuses the attention on asking for example on how productive capacity is evaluated, how the raw material plan is defined, which support is used to plan capacity requirements speaking about both productive plant and workforce. Which support is used to control the WIP status or to manage the documentation? The set of KPIs implemented for monitoring production and the kind of skills that characterized the production workforce of the company are themes that this part of the questionnaire explores.
- **Quality**: In this area are explored themes related with which quality checks are executed, how often results from quality tests are analyzed, if informative systems that allow tracking quality issues are utilized.
- **Maintenance**: maintenance section of the questionnaire asks question related with the maintenance policy adopted, with the kind of information that is managed inside the

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maintenance execution process. If the maintenance tools are connected to those for the diagnostic, for example.

- **Logistics** area deals with internal logistics, it asks if some lean practices have been implemented, if performances are measured, if WMS is used, for example.
- **Supply chain** asks for example how the demand planning process is structured, what tools are used to support the order-delivery-billing-payment active cycle. Moreover, how is structure the vendor rating, for example.
- **Strategy**: This section asks question related to industry solution implementation from a strategic point of view, how much the company thinks that they are important? The corporate culture is mature enough speaking about digital transformation subject? How much industry 4.0 initiatives have been already implemented?
- **Human Resources**: This area asks question related with the definition of leadership and coordination roles for the implementation of industry 4.0 strategy. How the human resource management function is involved in the development if the industry 4.0 strategy? Does a process for evaluating skills of employees in the implementation of Industry 4.0 strategy exists? Do you have training programs? Which is the level of digitization of human resource management processes?
- **Smart Product**: This area of the questionnaire ask question related with the smart features of the product, if the product is able to autonomously collect data and how this data are made available.
- **Marketing and Sales**: The questions related with this area deals for example with the kind of information about the company available online, the marketing policies about the brands, how the brand is presented, what are the sales channels used by the company.

In T2.3 of CAPRI project, only seven dimensions out of ten have been taken in consideration; human resources, marketing and sales, and smart product have been seen as redundant to the main goal of focusing the attention on business areas strictly related with the production plant: Design and Engineering, Production, Quality, Maintenance, Logistics and Supply Chain. Finally, also the "strategy" dimension of the test has been taken into consideration in order to keep a horizontal point of view a side of the first six business areas analyzed.

2.2 The Four Dimensions of Analysis

All the process areas mentioned, are analyzed in relation to **four dimensions of analysis** in order to evaluate for each dimension the current digital level of the processes.

Figure 2 – Test Industry 4.0 dimensions of analysis

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Monitoring & control: This dimension of analysis assesses the information pertaining the monitoring and control activities of a process, plant or factory. Along all the test, for example, this dimension looks at how the information are managed from the development to the production stage, how historical information are managed, which quality checks are conducted by the staff, how often data collected are analyzed. Ad again, how internal performance are measured, how the vendor rating system is structured.

Technology: This dimension includes information on the ICT hardware and/or software systems used to support the processes. For example, questions related to simulation tools utilization are asked, questions related with which systems are used to plan and schedule the production are utilized. Ad again, which technologies are used to support the inventory planning process? How physical flows are tracked?

Organization: It comprehends the information pertaining the organizational structure that underlies the execution of the processes. For example, how the production area is involved during the production development stage? How the quality department interact with the other company areas? What is the empowerment level of the maintenance team of your company?

Execution: It includes information on how a process is performed or managed. This area explores, for example, how the product concept is generated, how the planning of a product processing cycle is realized, if a company has defined a procedure to manage quality issues, if warehouse analysis to check the presence of spare materials that are critical for the plant are present.

2.3 The Maturity Scale

A **Maturity Scale** is taken into account and a five-point digital scale is structured as follows:

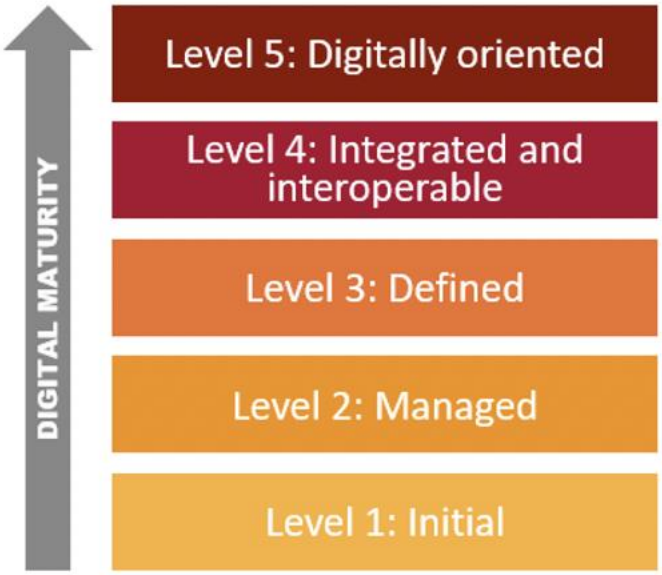

Figure 3 – Test Industry 4.0 Maturity Scale

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Maturity Level 1: Initial. The process is poorly controlled or not controlled at all.

For example, speaking about *Design and Engineering* business area and in particular about how the production area is involved during the product development stage, level 1 means that: "Information is shared just in one direction: from development to production department; there isn't any collaboration between them". Speaking about *Production* business area and in particular about which support is used to plan capacity requirements of productive plants, level 1 means: "The activity is not performed". Again, speaking about *Quality* business area and in particular about when quality controls are executed by expert staff, level 1 means: "Quality controls are executed only at the final test". And so on.

Maturity Level 2: Managed. The process is partially planned and implemented. The process is poorly controlled or not controlled at all.

For example, speaking about *Design and Engineering* business area and in particular about how the production area is involved during the product development stage, level 2 means that: "Information is shared from development to production area and viceversa, but there isn't any collaboration between them". Speaking about *Production* business area and in particular about which support is used to plan capacity requirements of productive plants, level 2 means: "The activity is performed using paper support". Again, speaking about *Quality* business area and in particular about when quality controls are executed by expert staff, level 2 means: "Quality controls are executed at the final test and during the process.". And so on.

Maturity Level 3: Defined. The process is defined with the planning and the implementation of good practices and management procedures.

For example, speaking about Design and Engineering business area and in particular about how the production area is involved during the product development stage, level 3 means that: "The production area collaborates with the development area starting since the early stages of the design process". Speaking about *Production* business area and in particular about which support is used to plan capacity requirements of productive plants, level 3 means: "The activity is performed using the Office tools (Excel, Access, Project). Again, speaking about *Quality* business area and in particular about when quality controls are executed by expert staff, level 3 means: "Quality controls are executed at the final test, during the process and at the acceptance stage". And so on.

Maturity Level 4: Integrated and interoperable. The process is built on information exchange, integration, and interoperability across applications; and it is fully planned and implemented.

For example, speaking about Design and Engineering business area and in particular about how the production area is involved during the product development stage, level 4 means that: "The production area collaborates with the development area and it is involved in the main phases of the design process". Speaking about *Production* business area and in particular about which support is used to plan capacity requirements of productive plants, level 4 means: "The activity is performed using a specific application developed for this purpose". Again, speaking about *Quality* business area and in particular about when quality controls are executed by expert staff, level 4 means:

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"Quality controls are executed at the final test, during the process and at the acceptance stage. Moreover, also reliability tests are executed". And so on.

Maturity Level 5: Digitally oriented. The process is digitally-oriented and is based on a solid technology infrastructure and on a high potential growth organization, which supports the decision making.

For example, speaking about Design and Engineering business area and in particular about how the production area is involved during the product development stage, level 5 means that: The production area collaborates with the development area, it is involved in the main phases of the design process and the two areas share skills and lesson learned. Speaking about *Production* business area and in particular about which support is used to plan capacity requirements of productive plants, level 5 means "The activity is performed using ERP". Again, speaking about *Quality* business area and in particular about when quality controls are executed by expert staff, level 5 means: "Quality controls are executed at the final test, during the process and at the acceptance stage. Moreover, also reliability tests are executed. At the end of this set of controls, a feedback about check results is sent to responsible areas, to update the risk evaluation, according to resulting data of defective products". And so on.

3 The 6Ps digital transformation journey and its dimensions

According to the DT methodology presented in Chapter 1, 6Ps represents the tool that covers the second step of the methodology, it regards setting a clear **digital transformation journey**. 6Ps digital transformation online survey is part of the **6Ps migration journey** and it aims at helping companies to generate strategies for approaching and moving forward Industry 4.0. It serves as a starting point and a basis for new ideas and roadmaps during a digital transformation process towards Industry 4.0. The migration journey has been developed inside universities boundaries and it has been already used in MIDIH European project.

The aim of 6Ps digital transformation tool is to assess the current level of digital maturity of manufacturing companies (AS-IS), quantify the desired level of digital maturity that these latter aim at achieving (TO-BE) and design a specific action plan to allow the transition needed to fill the gaps identified. The migration model is based on 6 pillars or rather 6 dimensions of analysis, which are Products, Process, Platform, People, Partnership and Performance. These pillars are clustered into 2 categories: **Technical Pillars** and **Socio-Business Pillars**.

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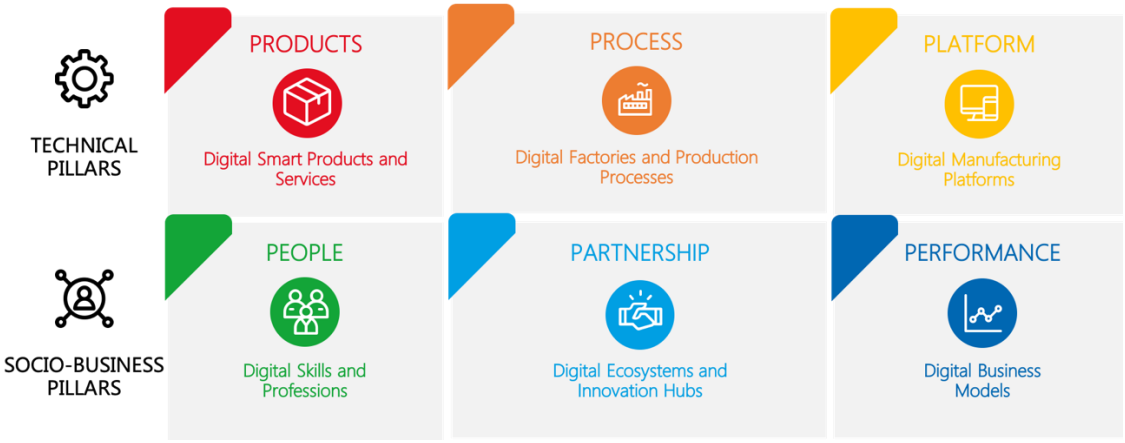

Figure 4 - 6Ps Digital Transformation Tool

Each dimension is composed of **six different** fields of analysis of Industry 4.0 (rows). Each analysis field is broken down into **five sequential development stages** (columns) from the least to the most advanced one with respect to Industry 4.0. 6Ps digital transformation tool supports manufacturing SME in shaping the best migration journey according to its digital maturity level, available resources and strategic objectives.

3.1 The Five Main Steps of the 6Ps Journey

1. **Set-up of a team bringing together different organizational areas**:
   Appointing a team that leads the digital transformation of existing socio-technical systems is crucial to demonstrate top management commitment and leadership to drive the overall transformation.

2. **Identification of the AS-IS profile of the manufacturing SME**:
   The manufacturing SME's strategy, competitive strengths and weaknesses, etc. must be analyzed. Then, its current profile must be mapped into each dimension and development stage of every migration dimension.

3. **Definition of the target TO-BE profile of the manufacturing SME**:
   The future vision and desired profile of the manufacturing SME must be defined considering the links to the business and competitive priorities, and thus mapped onto each dimension and development stage of the 6P dimensions.

4. **Identification of actions, feasibility and prioritization**:
   This step is about identifying the actions needed to migrate from the AS-IS to the TO BE and, considering the links to the business strategy as well as benefits and costs, risks and dependencies, evaluating to what extent investments are justified and what actions should be prioritized.

5. **Development of the Migration Plan towards Industry 4.0**.
   Finally, the migration plan is developed. In this respect, different approaches can be adopted. However, often the most successful one is to focus on simple actions with short-term pay-offs at first (quick wins) before implementing more complex and long-term projects.

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Figure 5 summarizes the five steps of the journey.

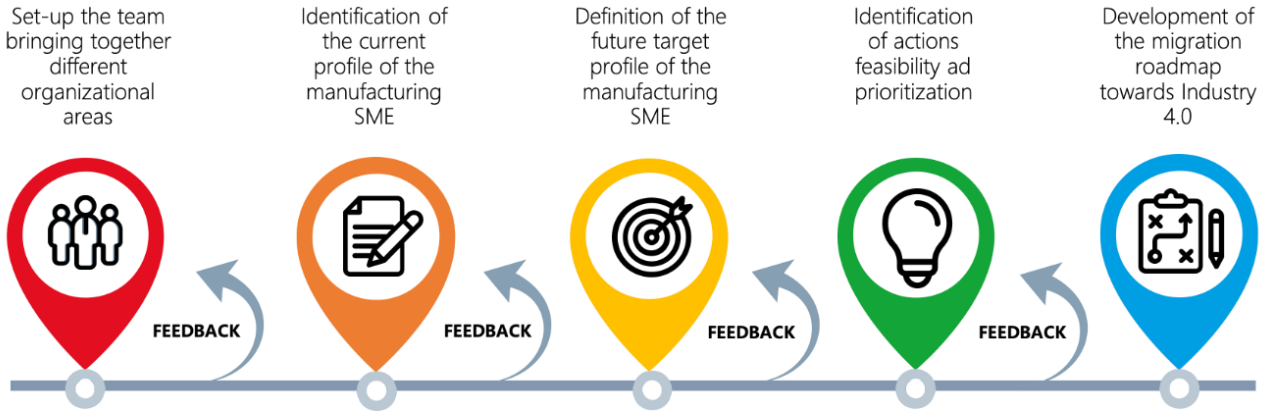

Figure 5 - The 5 steps of the 6Ps Journey

Inside T2.3 of CAPRI project, the first three steps have been conducted. Together with the representant from asphalt, pharma and steel industry, the identification of the current profile and the future target of the company have been put in light. Before filling the 6Ps online survey, each company set-up a team bringing together several representant form different company's area, then, they complete the survey keeping in mind the AS-IS situation of the company and the TO-BE target desired with the end of the project. The last two steps are still missing, to complete the migration journey it will be necessary to identify and prioritize the feasibility actions in order to reach the desired TO-BE level. Finally, the migration plan is developed and the plan needs to be effectively followed.

3.2 The Product Dimension

6Ps' **Product dimension** has the objective of evaluating in a quantified way to which extent the manufacturing SME is digitally mature un terms of Product or Product-Service System that offers to the market. This is the first dimension analyzed as the subject of the analysis constitutes the direct link that manufacturing SMEs have with their customers thus significantly affecting the overall performances of the firms.

The six different fields of analysis that are taken into account are related to: **Sensors and actuators** (to understand how the product is equipped); **Communication and Connectivity** (to measure how the product is able to communicate with external devices); **Storage and Exchange of information** (to measure if the product is able to storage data); **Monitoring** (to assess if the product is able to self-monitor its status); **Product-related IT services** (to measure the level of service related to the

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product); **Business Models enable by the product** (to measures how the digital maturity of the product impact on company's business model).

Industry 4.0

	LEVEL-1 INITIAL	LEVEL-2 MANAGED	LEVEL-3 DEFINED	LEVEL-4 INTEGRATED	LEVEL-5 EXPLOITED
INTEGRATION OF SENSORS / ACTUATORS	no use of sensors/ actuators	External sensors/actuators are integrated	sensors readings are processed by the product	sensors and other data sources are analysed inside the product	the product is able to autonomously respond to the ambient
COMMUNICATION / CONNECTIVITY	the product has no communication interfaces	the product sends or receives I/O signals	the product has field bus interfaces	the product has industrial ethernet interfaces	the product is securely connected to the internet
STORAGE AND EXCHANGE OF INFORMATION	no functionalities	possibility of individual identification	product has passive data store	product with data storage for autonomous information exchange	data and information exchange as integral part
MONITORING	no monitoring by the product	detection of failures	recording of operating conditions for diagnostic purposes	prognosis of its own functional condition	monitoring at the basis of decisions and prescriptions
PRODUCT-RELATED IT SERVICES	no IT services correlated to the product	product-related services adjunct via online portals	service provision and execution performed directly via the product	product intended as a service platform	complete integration of the product into an ecosystem of product-service systems
BUSINESS MODELS ENABLED BY THE PRODUCT	main revenue streams from selling standardized products	sales and consulting services regarding the product	sales, consulting and adaptation services for customised products	services as decisive factor for additional sales of products	main revenue streams from selling product related services

Figure 6 - 6Ps - The Product Dimension

3.3 The Process Dimension

6Ps' **Process dimension** has the main objective of assessing the level of digital maturity in each of the most relevant processes that characterize the manufacturing sector and so manufacturing SMEs. The areas investigated as well as the methodology adopted to propose the survey at first and to conduct the interviews is directly linked to the methodology of the DREAMY 4.0 Assessment tool.

The six analysis fields are related to: **Design & Engineering** (to evaluate how these two processes are enabled by digital technologies); **Production Management** (to evaluate how the production happens); **Quality Management** (to assess how quality is managed to avoid quality issues); **Maintenance Management** (to measure how much digital technologies characterize the practices related maintenance activities); **Logistics Management** (to assess the digital maturity level of the logistics processes); **Supply Chain Management** (to evaluate to which extent digital technologies are exploited in this field).

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Industry 4.0

	LEVEL-1 INITIAL	LEVEL-2 MANAGED	LEVEL-3 DEFINED	LEVEL-4 INTEGRATED	LEVEL-5 EXPLOITED
DESIGN & ENGINEERING	No digital model of the process is present. There are only one-way exchanges between design and production functions	Some preliminary digital models do exist as static representation of the process. Notifications between production and design functions are bidirectional, but tracked in a document	Simulations are developed inside the CAD and supported by digital models. Production function is involved in all the design process. Modifications are tracked via different digital models, with an internal encoding	Simulations are developed and validated in CAD environment; digital models are compared versus physical prototypes. Production function is totally involved in the design phase. Modifications are automatically identified and managed in CAD.	Full Digital Twin simulations developed in CAD environment are used. Production function is totally involved within the design phase and skills of the two functions are shared. Different digital process options are managed and assessed in a single development environment.
PRODUCTION MANAGEMENT	Repetitive production processes are partially automated but not connected, with significant human intervention. Repetitive support processes are not automated.	Repetitive production processes are almost automated and connected via multiple channels and protocols. Repetitive support processes are not automated.	Repetitive production processes are fully automated and interoperable, with no human intervention. Repetitive support processes are partially automated.	Automated and interoperable production processes are reconfigurable through plug-and-play automation and capable of real-time communication. Repetitive support processes are partially automated.	Flexible and interoperable production and support processes are capable of real-time communication, scalable and converged with enterprise and facility automation platforms to form highly autonomous networks.
QUALITY MANAGEMENT	Quality processes are carried out through human inspections and simple systems (e.g. excel control charts) (descriptive quality)	Quality management systems are able to model correct quality patterns and identify deviations. (diagnostic quality)	Quality management systems are able to identify deviations and diagnose potential causes. (preventive quality)	Quality management systems are able to diagnose problems and predict future states of assets and systems. (predictive quality)	Quality management systems are able to diagnose problems, predict future states and autonomously execute decisions to adapt to changes (cognitive quality).
MAINTENANCE MANAGEMENT	The company does not use any digital tool to track maintenance activities and adopts a descriptive approach	The maintenance activities are tracked with simple tools (e.g. excel sheets) and plans and procedures are loaded into CMMS/ERP. The company adopts a diagnostic approach	The maintenance activities are tracked and analysed with simple tools (e.g. FMEA on excel sheets) and reconfigurable plans and procedures are loaded into CMMS/ERP. The company adopts a predictive approach	Maintenance activities are traced and monitored through dedicated software (e.g. CMMS, SCADA, MES, etc.) procedures and plans are validated periodically. The company adopts a prescriptive approach.	Maintenance activities are traced and monitored through dedicated software (e.g. CMMS, SCADA, MES, etc.) procedures and plans validation is part of the maintenance activity. The company adopts a cognitive approach.
LOGISTICS MANAGEMENT	Logistics processes are defined and executed by humans, with the support of analogue tools	Defined logistics processes are completed by humans with the support of digital tools.	Digitized logistics processes and systems are securely integrated across all hierarchical levels of the automation pyramid.	Integrated logistics processes and systems are automated, with limited human intervention	Automated logistics processes and systems are actively analysing and reacting to data
SUPPLY CHAIN MANAGEMENT	Process barely monitored and managed reactively. Systems not updated nor integrated	Process lowly monitored, managed on experience. Systems antiquates or not integrated.	Use of good practices. Process fairly monitored, partially integrated and automated	Use of best practices and common and shared standards. Process overall planned and monitored. Systems mainly integrated, automated and managed in an overall integrated way among divisions.	Process is systematically monitored, developed with advanced technologies and systems that are managed in an integrated way among divisions. Information exchange is fast, robust and secure.

Figure 7 - 6Ps - The Process Dimension

3.4 The Platform Dimension

The Platform Matrix suggests migration pathways towards Digital Platforms supporting vertical integration (from the shop floor to the enterprise level), horizontal integration along the value chain and end-to-end engineering.

In this respect, six technological fields of analysis are considered: **CPS and embedded systems** (to measure how much the firm is able to use the data collected from the field); **Industrial Internet of Things** (to measure the ability of the factory in using and integrate IoT devices); **Industrial Internet** (to measure how factory assets are linked to the common internet platform); **Industrial analytics** (to evaluate the capacity of the company in exploiting analytics); **Vertical interoperability of data and events** and **Horizontal interoperability of data and services** (to measure the capabilities of manufacturing companies in collecting, manipulate and manage data that are necessarily heterogenous in an integrated way).

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Industry 4.0

	LEVEL-1 INITIAL	LEVEL-2 MANAGED	LEVEL-3 DEFINED	LEVEL-4 INTEGRATED	LEVEL-5 EXPLOITED
CPS AND EMBEDDED SYSTEMS	No Digital Manufacturing Platforms in Smart / Embedded Systems	Just the capability to collect and store data from the field and elementary elaboration (datalogger)	In addition to storage/computation, the capability to integrate additional sensors, to understand the ambient and to react correspondingly	In addition, the capability to set up and manage Machine2Machine and Machine2Human interaction sessions	The capability to use the collected information (from machines, from sensors and from human interaction to take decisions and behave autonomously)
INDUSTRIAL IoT	No capability to sense the ambient and react	Dumb sensors provide data but cannot neither commanded nor configured remotely	Sensors ecosystems are governed and controlled by dedicated hardware usually at the edge of the network	A computable model of the asset allows running simulations and forecasting behaviour	Ecosystems of smart objects are interoperable through open standards
INDUSTRIAL INTERNET	Real World devices are controlled and managed by hard wired protocols	Real World devices are controlled and managed by multi-protocol gateways	Events gathered by gateways are processed and anomalous situations detected by threshold analysis	More complex knowledge and rules are used to determine correct and anomalous patterns	On-the-fly configurable HCI primitives and adaptive and cognitive analytics reports
INDUSTRIAL ANALYTICS	No Digital Manufacturing Platform for analytics functionality	Analytics techniques are used to filter and visualise data sets (streams or repositories)	The system under analytics is modelled and dynamic behavioural simulations allowed as well as model verification and validation form real world data	Verified model are used to instantiate what-if scenarios, to forecast them and to predict future behaviours	The future predicted scenarios are confronted with current plans and decisions in Enterprise Applications, so that new business decisions are generated
VERTICAL INTEROPERABILITY OF DATA AND EVENTS	Data Events at Shopfloor unexploited	Data generated by real world are collected by dedicated Data Loggers and Gateways	Data generated by real world are transferred through the gateways to the cloud	Bidirectional data flows between real world and cloud allowed by an architecture of distributed HW/SW components	At runtime and on-the-fly the configuration of the distributed architecture could be dynamically adapted
HORIZONTAL INTEROPERABILITY OF DATA AND SERVICES	Data/Events silos	Data coming from different plants are integrated ad- hoc in a unique repository	Different data formats and protocols are semantically harmonised and interoperated	Different Enterprise Applications in different factories are integrated as a service	Collaborative business processes and workflow are implemented in the value chain

Figure 8 - 6Ps - The Platform Dimension

3.5 The People Dimension

6Ps' **People dimension** aims at assessing the skills owned or to be owned among manufacturing SMEs' human capital. This dimension is not divided into 6 areas directly, due to the high variance in the roles operating in the sector, this pillar has been at first divided into 3 macro-professions, namely: Operators & Technicians, Professional & Engineers and Managers & C-Levels.

6 fileds of interest have been identified as well. These areas are: **Industry 4.0 Strategy** (to measure the level of awareness about industry 4.0); **Smart Operations** (to evaluate how much digital technologies are exploited in favor to traditional tools); , **Smart Supply Chain** (to assess the level of digitalization of tools utilized in this field), **Smart Product-Service Engineering** (to evaluate the skills and tools utilized in the production development phase), **Industry 4.0 Infrastructure** and **Big Data** (to assess the level of skills in the field of big data).

The figure below shows the 6 fields composing the People dimension and their divisions into the 3 macro-professions.

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Industry 4.0

		LEVEL-1 INITIAL	LEVEL-2 MANAGED	LEVEL-3 DEFINED	LEVEL-4 INTEGRATED	LEVEL-5 EXPLOITED
INDUSTRY 4.0 STRATEGY	MANAGER	Know and understand the trends related to Industry 4.0 and changes in the competitive environment	Analysing the transformation of the value chain by adopting Industry 4.0	Provide leadership for the creation of an Industry 4.0 strategy and include risks and opportunities	Forge relationships and alliances with the various stakeholders of the Industry 4.0 ecosystem	Apply strategic thinking, stakeholder management and organizational leadership to develop and implement an integrated strategy to exploit the capability of I4.0 technology to improve the business
SMART OPERATIONS	OPERATOR	Use standard HMI	Use wearable devices to monitor production	Analytical skills to interpret production data	Use of new production tech. (e.g. collaborative robotics, 3D printing etc.)	Plan, monitor, analyse information, inspect (with AR) determine causes of problems/failures and perform corrective actions
	PROF/MNG	Use of common software (e.g. excel)	Use of Enterprise Systems (ERP MES PLM)	Analytical skills to analyse production data autonomously and interpret production data	Redesign processes end-to-end to improve their performance through I4.0 technologies	Plan, coordinate, optimize smart production systems
SMART SUPPLY CHAIN	OPERATOR	Use of common software (e.g. excel)	Use of wearable devices	Analytical skills to interpret data	Use/interaction of new smart warehouses, picking and automatic guided vehicles	Plan, monitor, analyse information, inspect (with AR) determine causes of problems/failures and perform corrective actions
	PROF/MNG	Use of common software (e.g. excel)	Dynamic management in real time through monitoring and tracking technologies	Collaborate with different external actors and integrate them in the digital supply network	Analyse market demand, supply network data, social media and other data, and predict future scenarios	Plan, coordinate, optimize the collaborative digital supply network
SMART PRODUCT-SERVICE ENGINEERING	TECHNICIAN	Use of technical drawing programs (CAD)	Drawing in 3D	User skills for 3D printing AR/VR	Design of smart products (integration of sensors, antennas, chips and other components)	Model-based design and Simulations
	PROF/MNG	Product-oriented organization and business models	Understanding the importance to follow the whole lifecycle of the Product and support services	Design smart products customized through sw user interface and services, integration with the enterprise IT systems	Design and management of the product-service lifecycle and Business Models	Open innovation of smart PSS lifecycle and B.M. with a digital ecosystem of partners.
INDUSTRY 4.0 INFRASTRUCTURE (IT_OT)	PROF	Contribute to the design and general functional specification and interfaces	Use of modelling languages and programming tools	Evaluation of pros and cons of different sensors, software, protocols and select the most adequate to the needs of the enterprise (including cybersecurity)	Specify, refine, update and make available a formal approach to implement solutions, necessary to develop and operate the architecture oriented towards Industry 4.0	Investigating latest technologies and devising innovative solutions for integration of new technology into existing systems to meet future business Industry 4.0 requirement
BIG DATA	PROF	Selecting and collecting useful data	Cleaning, organising and rationalising the data	Selecting and implementing technology for analysing big data	Clean business insights from big data (algorithms)	Using big data creatively and innovatively

Figure 9 - 6Ps - The People Dimension

3.6 The Partnership Dimension

Partnership Matrix relates to the identification of the partners needed for digitalization and for achieving the desired business goals. IT describes the workflows whose purpose is to support the transition towards more collaborative relationships with key stakeholders in the digital ecosystem, in order to create strong and collaborative partnerships that are crucial for the SME. Partnership is intended as a lever to be sustainable in the long term and CAPRI DIH ecosystem can be the place where partnerships may arise.

Accordingly, partners included in the dimensions are: **DIHs** (to establish the level of engagement the company has established or is willing to establish with DIHs); **Research and Innovation** (to measure the level of engagement that the firm has with these typologies of institutions); **Education and Training Providers** (the level of collaborations between partners and institutions such as universities are quantified); the same with **IT Solution Providers**, **Suppliers and Customers**.

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Industry 4.0

	LEVEL-1 INITIAL	LEVEL-2 MANAGED	LEVEL-3 DEFINED	LEVEL-4 INTEGRATED	LEVEL-5 EXPLOITED
DIGITAL INNOVATION HUBS	No relationship with Digital Innovation Hubs	Informal communication one-off share of information	Supportive relationships but no formal activities in place	Engaged in mutual projects and initiatives	Formal agreement in place, partners work toward developing enhanced capacity
RESEARCH & INNOVATION	No relationship with research /innovation organizations and programs	Participation to events and workshops oriented to research and innovation	Active interest in Research & Innovation initiatives	Occasional participation to R&I programs	Systematic Participation and common Research & Innovation programs
TRAINING & EDUCATION	No competence assessment and training programs on Industry 4.0	Occasional competence assessment and educ./training programs for a few roles	Regular competence assessment, training and education programs, also in collaboration with VET schools, universities, etc.	Use of Technology-Enhanced Learning in collaboration with VET schools, universities, etc.	Lifelong learning programs for the whole staff leveraging technology-enhanced learning. On-going collaboration with education through staff exchange, learning factory., etc.
IT SOLUTIONS PROVIDERS	No continuative relationship	IT partnership as a necessary provision of basic digitalisation services (suppliers)	IT partnership as a collaboration environment to develop together reliable solutions	IT providers as reliable partners in identification of new business opportunities	IT providers as offering game changing value and new business models
SUPPLIERS	Transaction relationship: partnership just related to the supply of goods/services	Cooperation relationship: partnership also related to the supply and usage of goods/services	Coordination relationship: partnership also related to whole ecosystem of goods/services suppliers	Collaboration relationship: partnership directed to a mutual but occasional business opportunity	Dynamic collaboration relationship: strategic long-term multi –dimensional partnership in a win-win situation
CUSTOMERS	No partnership with Customers	Cosmetic customer partnership. standard product is offered in different ways to different customers using special packaging, etc.	Transparent Customer Partnership. Customization without direct interaction with customers	Adaptive Customer Partnership. Customer customizes the good or service as desired using customizable functionality embedded into the offering	Collaborative Customer Partnership. Customers actively participate in Co-creation and co-production

Figure 10 - 6Ps - The Partnership Dimension

3.7 The Performance Dimension

6Ps' **Performance dimension** aims at investigating what the role that Industry 4.0 technologies have in the definition, monitoring and interpretation of KPIs of the manufacturing SMEs.

The dimension is divided into 6 areas, namely: **Operational/Technical** (to monitor the performances of machines and production activities such as OEE); **Economic** (to monitor KPIs focused on economic and financial results such as ROI); **Environmental** and **Social** (to measure these performances and covering all the aspects of the triple bottom line); **Product-Service Lifecycle** (to assess how, to which extent and according to which criteria the Product is assessed by the firm once offered to the market); **Supply Chain** (to assess the modalities through which manufacturing SMEs are able to measure the overall performances of their entire Supply Chain)

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Industry 4.0

	LEVEL-1 INITIAL	LEVEL-2 MANAGED	LEVEL-3 DEFINED	LEVEL-4 INTEGRATED	LEVEL-5 EXPLOITED
OPERATIONAL/ TECHNICAL	Operational performance is often not measured or understood	Descriptive Performance - Measurement and analysis of business KPIs are largely retrospective	Diagnostic Performance - Measurement of KPIs is clear. Attempt to understand the causes that affects events and behaviours	Predictive Performance - Measurement of KPIs is prospective. Statistical models and forecasts techniques to understand the future KPIs	Prescriptive Performance – future-oriented. Optimization and simulation to find the best course of action and operational KPIs measurement
ECONOMIC	Economic performance is often not measured or understood	Descriptive – Measurement of economic KPIs is largely retrospective	Diagnostic - Measurement of economic KPIs is clear. Attempt to understand the causes of events and behaviours	Predictive - Measurement of economic KPIs is prospective. Statistical models and forecasts techniques to understand the future	Prescriptive – future-oriented. Optimization and simulation to find the best course of action and economic KPIs measurement
ENVIRONMENTAL	Environmental performance is often not measured or understood	Descriptive – Measurement of environmental KPIs is largely retrospective	Diagnostic - Measurement of environmental KPIs is clear. Attempt to understand the causes of events and behaviours	Predictive - Measurement of environmental KPIs is prospective. Statistical models and forecasts techniques to understand the future	Prescriptive – future-oriented. Optimization and simulation to find the best course of action and environmental KPIs measurement
SOCIAL	Social performance is often not measured or understood	Descriptive - Measurement of social KPIs is largely retrospective	Diagnostic - Measurement of social KPIs is clear. Attempt to understand the causes of events and behaviours	Predictive - Measurement of social KPIs is prospective. Statistical models and forecasts techniques to understand the future	Prescriptive – future-oriented. Optimization and simulation to find the best course of action and social KPIs measurement
PRODUCT-SERVICE LIFECYCLE	No product life cycle assessment	A few life-cycle aspects are included in some KPIs but occasionally	Life Cycle Costing (LCC) towards recycling, de-re-manufacturing KPIs	Life Cycle Costing + Environmental LCA towards Circular Economy	Life Cycle Costing + Environmental LCA + Social LCA towards Sustainability and Green Deal
SUPPLY CHAIN	Performance is often not measured or understood	Only the most important physical performance of suppliers (e.g. punctuality, quality, operational flexibility)	Physical and Economical performance (purchase price, non-quality costs, delivery delays, lack of flexibility, etc.).	Physical, economical, sustainability performance for almost all the suppliers.	Physical, economical, sustainability and integration with other external sources (e.g., social media, weather)

Figure 11 - 6Ps - Performance Dimension

4 Test Industry 4.0 Validation and Results

As presented in paragraph number 2, Test I4.0 is an online questionnaire utilized from companies in order to reach the awareness of their digital maturity level. Test i4.0 is part of a structured method called DREAMY 4.0 Assessment Tool. Dreamy methodology has been developed thinking about discrete manufacturing and, as a consequence, also Test I4.0 born with a high customization for discrete industries. For this reason, before start implementing this tool among CAPRI's use cases, suggestions and validations have been asked and collected from CAPRI's experts in order to customize the online questionnaire for process industry.

Two webinars have been organized in order to meet partners and show them POLMI digital transformation methodology. Speaking about Test industry 4.0, two dedicated webinars have been organized in order to meet all the partners interested. During the first one, Steel and Pharma companies have been met, during the second one, Asphalt and ICT entities have been encountered. The test has been explained together with its sections and its final goal. Where a contribution from CAPRI's partners was needed and how was the plan to collect contributions has been clarified. The questionnaire and an excel template to collect contributions have been prepared and circulated among partners, thanks to this, many suggestions about different Test I4.0's areas have been collected in a structured way. Analysing comments and merging results coming from different partners operating in different sector the validation of the test has been conducted and an updated version of the Test customized for process industry has been released with CAPRI's partners in

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order to be filled. In the following lines, using bullet points have been reported some of the most meaningful modifications collected and reported to the new updated version of the test.

1. In process industry doesn't make a lot of sense speaking about "**Engineering-to-order**" logic, at the same way "design" is not an effective term to be used in process industry, so that the concept have been substituted with a more generic word: "**development**".
2. **CAD** (Computer-Aided Design) software reference have been deleted, in discrete manufacturing it supports the manufacture project and design activity (e.g.providing 3D model of the product) but in process industry is not typically utilized.
3. Bill of Material (**BOM**) is a tailored concept for discrete manufacturing but in process industry it has been better substituted with the concept of "**list of ingredients**".
4. "**Assembly**" and "**Bulk**" concepts have been deleted from all the questionnaire's areas.
5. The terms "**semi-finished**" product has been substituted with the more general concept of "**WIP**".
6. Speaking about logistic area, in process industry makes not a lot of sense implementing a **WMS** system in order to trace raw materials, at the same way, with raw materials for process industry is exaggerated speaking about **AGV**s robots, roller conveyors or cantilevers, for this reason, these concepts have been deleted and new ones (e.g., **Tank)** have been added.
7. More generally some questions have been deleted, others have been added. At the same way, this happened among answer's alternatives. Text's composition and writing structure has been revised in order to reach a clearer presentation of the questionnaire.

In the following paragraphs, the results of the online survey filled out have been reported and commented. One representative from each sector has filled the online Test I4.0: AMS for Pharma Industry, SID for Steel Industry and EIFF for Asphalt sector. In detail, from AMS Joerg Breitenbach has been committed, from EFF Rafael Martinez and from SID Asier Arteaga.

As already said in Chapter 3, In T2.3 of CAPRI project, only seven dimensions of the Test Industry 4.0 have been taken in consideration; human resources, marketing and sales, and smart product have been seen as redundant to the main goal of focusing the attention on business areas strictly related with the production plant: Design and Engineering, Production, Quality, Maintenance, Logistics and Supply Chain. Finally, also the "strategy" dimension of the test has been taken into consideration in order to keep a horizontal point of view a side of the first six business areas analyzed. In the future will be evaluated if proposing also the missing three dimensions.

The pilots had the availability of choosing if filling out all the seven dimensions proposed or considering only some of them, according to their knowledge and to the possibility in propagating company's sensitive information.

4.1 Results from Asphalt Industry (EIFF)

Eiffage Infrastructuras (EIFF) is one of Europe's leading operators in construction and concessions. The company, with 72,500 employees work in construction, real estate, urban development, civil engineering, metallic construction, roads, energy systems and concessions. Inside CAPRI project, it represents the pilot related with **Asphalt Industry**.

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EIFF answers to all the seven dimensions of the Test I4.0 proposed, according to the results visible in Figure 12, in the following lines a comment has been provided.

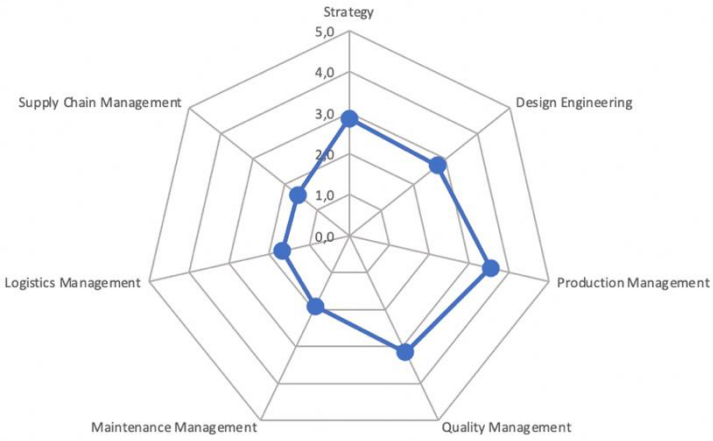

Figure 12 - Maturity Level for Business Area - EIFF

Speaking about ***strategy*****,** a level 3 of digital maturity has been recorded. The company is conscious about the importance of industry 4.0 solutions inside its sector, at the same time the respondent answered that inside production plant not meaningful I4.0 solutions have been adopted yet.

Speaking about ***Design & Engineering***, level 2,8 of digital maturity has been reached, for example, in the concept-generation phase the company re-use many set of data generated from previous product, data are easily trackable and accessible, thank to this, high efficiency is reached. The company doesn't use digital simulation tools during the concept validation phase, physical prototypes are preferred. The production area highly collaborates with the development one but the list of ingredients is locally stored in different offices and in spreadsheet form, doesn't exists a single data archive yet. The company tries to implement lean and agile approaches, for example, they usually start from the definition of a minimum valuable product (MVP). The planning of a product processing cycle is usually performed using some supporting tools that are still not well integrated.

Analysing ***Production*** dimension, from the test, the company registered a 3,5 level of digital maturity, in fact, even if production planning is mainly base on people experience and it is not based on any lean management logics, the production process as a whole is quite well evolute. The information required for drafting aggregate production plan are easily available and frequently updated. The plan for evaluating productive capacity and raw material supply is well defined, specific applications have been developed in order to support the planning of capacity requirements, the execution of productive activities, to support the WIP status and to create reports about the status of machineries and plants. The majority of workforce perform sectorial activities, there is a percentage of workers periodically trained to work in different sectors. The historical information available by monitoring production technical performances are not systematically analysed, the same inefficiencies has been registered speaking by production costs monitoring.

Speaking about ***Quality***, the company registered a 3,2 level of digital maturity. The expert staffs execute quality controls in different stages of the production process, the company has a clear procedure to manage quality issues. Inside the company is not performed a risk analysis to draft the control plan, it is still totally based managers 'experience. At the same way, issue causes are

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analysed according to personal experience and not following structured methods. Data resulting from quality tests are periodically analysed, moreover, the quality department highly collaborates with other company areas to analyse issues and to define the resolution actions.

Speaking about the last three dimensions, EIFF registered a lower level of digital maturity, 1,9 for ***Maintenance***; 1,7 for ***logistics*** and 1,6 for ***supply chain*** process.

Speaking about ***Maintenance***, part of the activities is performed by qualified employees of the company, others are in charge of external people via outsourcing contracts. The maintenance plans are defined according to the experience of workers. Maintenance happens only over the issue, there is not preventive maintenance, for example. The company doesn't perform deep analysis of data using specialized software, decisions are taken according to information deriving from last inspections. The maintenance department interact with the production one without following a structured approach.

Speaking about ***Logistics*****,** there are no technologies used to operationally control the positioning of materials inside warehouses, no specific methods and processes are utilized to allocate them. At the same time, places where internal stocks are kept are well marked, orderly and clean. Picking raw materials are guided by paper orders, rout optimization is left to the operator. There is not a periodic revision process for warehouses sizing.

Finally, speaking about ***Supply Chain***, there is an annual budget both for sales and production but it is not reviewed during the year. Excel sheets are used to support both demand planning processes and inventory planning processes. Documents of the order cycle are exchanged with suppliers through traditional channels, without using dedicated electronic links, for example.

The average between the seven dimensions analysed is 2,5, according to the maturity scale, the company stays between a *managed* and *defined* level.

Level 2: Managed	The process is partially planned and implemented.
Level 3: Defined	The process is defined with the planning and the implementation of good practices and management procedures

4.2 Results from Pharma Industry (AMS)

Applied manufacturing Science (AMS) is a privately specialised company in applying advanced manufacturing science, it is located in Poznan, Poland. AMS's teams consist of highly-trained professionals from the pharmaceutical industry and research. Inside CAPRI project, AMS represents the pilot committed with **Pharma Industry**.

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AMS focused the attention on four of the seven dimensions of the survey, Strategy, Design & Engineering, Production Management and Quality management have been taken into account. According to the results visible in figure 13, in the following lines a comment has been provided.

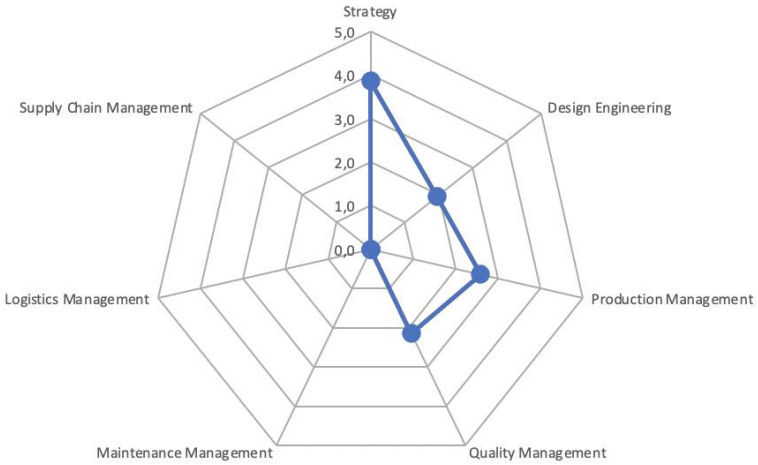

Figure 13 - Maturity Level for Business Area - AMS

Speaking about ***Strategy***, the company registered a medium-low level of digital maturity: 2,2 out of 5. In fact, the company believes that innovation related to industry 4.0 are important but not fundamental in its sector, some industry 4.0 activities inside company's boarders started but seems that company's culture is not ready enough to invest a lot towards this transition.

Considering ***Design & Engineering*** dimension, the digital maturity level is set around 2, for example, in the concept generation of a new product, the data re-use is small, about the 10-25% of data is inherited from previous concepts of similar products. Digital simulation tools are scarcely used because physical prototypes are still widely preferred. The list of ingredients for product development is handled in spreadsheet form and shared using a storage system protected by password. Product change requests are written in spreadsheet and processed following the creation order, without any priority.

Speaking about ***Production***, the company registered a maturity level of 2,6 points. Generally, the production planning is based on people experience and tailored to commercial solutions, no highly innovative software is implemented. In order to plan capacity requirements of productive plants, to control the execution of productive activities, to manage material flow and to control the WIP status, Office Tools are used. The same software is used to create reports about workers efficiency and process times of production batches, for example. The majority of the workforce performs sectorial activities, as result of a high distribution of operations; however, there is a percentage of workers periodically trained to work in different sectors and with skills applicable to different activities. Finally, historical information available by monitoring production costs and technical performances are not frequently analyzed.

Now, speaking about ***Quality***, the company registered a value of digital maturity settled at 2,1. The company implemented some procedures to control both the production quality and the supplies, quality controls are executed at the final test and during the process, exists a procedure to manage quality issues based on the quality measurement of WIP. Data traceability occurs using independent systems and data collection is hard and slow. There isn't any software that allows to directly access

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and analyze data. Related to this, there isn't a periodic scheduling to analyze data resulting from tests and quality checks. Anyway, the quality department highly interact with other company areas in order to analyze issues and to define resolution actions.

The average between the four dimensions analysed is 2,2, according to the maturity scale and relating to Strategy, Design & Engineering, Production Management and Quality Management, the company stays between a *managed* and *defined* level.

Level 2: Managed	The process is partially planned and implemented.
Level 3: Defined	The process is defined with the planning and the implementation of good practices and management procedures

4.3 Results from Steel Industry (SID)

Sidenor (SID) is a steel company leader in European steel industry for the production of special steel long products. It is also an important supplier of cold finished products in the European Market. Inside CAPRI project, SID represents the pilot committed with **Steel Industry**.

SID focused the attention on five of the seven dimensions of the survey, Strategy, Production Management, Quality Management, Maintenance and Logistics have been taken into account. According to the results visible in figure 14, in the following lines a comment has been reported.

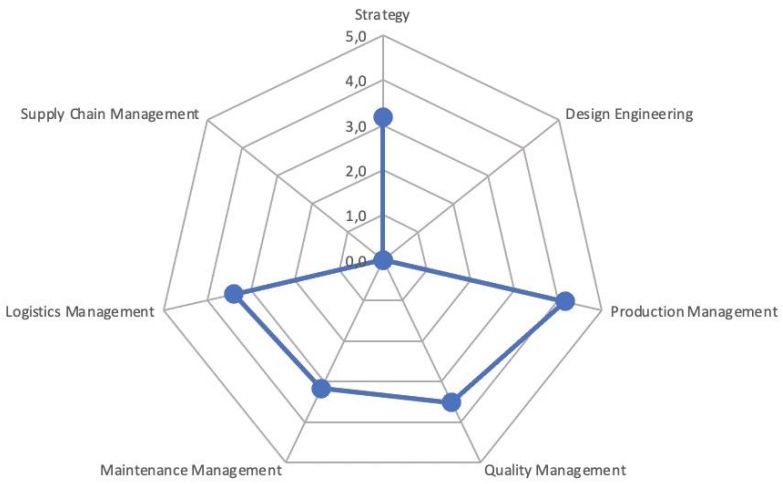

Figure 14 - Maturity Level for Business Area – SID

Speaking about ***Strategy***, the company believes that Industry 4.0 solution are highly important and they will be highly effective, the company thinks to have a quite good competitive level comparing with other competitors. Anyway, not many I4.0 initiatives have been internally introduced and the company culture seems not to be highly oriented towards innovation.

Speaking about ***Production Management***, the company registered a high level of digital maturity: 4,2. For example, production plans are based on historical demand data (e.g., MRP), the majority of

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information required to draft the production aggregated plan is easily available and the planning frequency is appropriate to follow the market demand. The plan for raw material supply is defined via the common MRP process (Material Requirements Planning), taking into account constraints of the productive capacity (inside the owned plants) and constraints of third part provisioning. The company implemented an ERP and different activities are supported by this (e.g., planning capacity requirements of productive plants, planning capacity requirements, manage work orders, control WIP status etc.). Historical information is systematically stored and used, by proper tools used to analyse costs' trends, in order to forecast and avoid production problems.

Now, speaking about ***Quality***, the company register a level of digital maturity settled at: 3,5. For example, there are in place some procedures to control both the production quality and the supplies and also commercial agreements are clearly defined and reviewed. Moreover, it has been defined a development plan for the product and the process, that includes reviews, checks, controls and quality validation. Quality controls are executed at the final test, during the process and at the acceptance stage. Moreover, also reliability tests are executed. At the end of this set of controls, a feedback about check results is sent to responsible areas, to update the risk evaluation, according to resulting data of defective products. Anyway, risk analysis is not performed to draft the control plan is not performed but is based on the manager experience. There exists an automated system that allow to track and to access data related to production quality measurements and to support the analysis of such data. Data resulting from tests/quality checks are periodically analyzed. The quality department interact a lot with other company areas.

Speaking about ***Maintenance***, a 3,2 level of digital maturity have been reached. For example, maintenance plans are defined according to the experience of workers involved in managing them. Autonomous and preventive maintenance is applied in all plants of the company. The maintenance department interact a lot with the production one in order to define maintenance plans.

Finally, speaking about ***Logistic management***, from the survey the company registered a level of 3,4 speaking about digital maturity. For example, speaking about warehouse control, inside the company, the warehouse locations are well identified, the positioning of the material is managed and controlled through a local WMS (Warehouse management system). Throughout the warehouse, including the storage areas on the machine, the company applies the basic principles of lean: the places where stocks are kept are well marked, orderly and clean, and error-proof; working methods are standardized. Anyway, only some internal logistics performances are measured by technical indicators.

The average between the five dimensions analysed is 3,5, according to the maturity scale and relating to Strategy, Production Management, Quality Management, Maintenance and Logistics Management, the company stays between a *Defined* and an *Integrated* level.

Level 3: Defined	The process is defined with the planning and the implementation of good practices and management procedures
Level 4: Integrated and Interoperable	The process is built on information exchange, integration, and interoperability across applications; and it is fully planned and implemented.

4.4 Cross-Domain Analysis in Process Industry

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CAPRI project involves the already mentioned three domains: Asphalt, Steel and Pharma. There are some common aspects that these companies face in their business. Nevertheless, CAPRI will try to improve and to solve some of operation-related issues that the partners pointed out.

A cross domain criticality, common to all the domains, is the need to have a holistic view of the production, thus data coming from the field have to be collected in order to provide information, possibly in real-time, on the state of the process. A second common issue is that for Asphalt and Steel domain, the energy consumed during production is really high, thus the necessity for both of them to optimise the production parameters, trying to lower it. The same optimisation of process parameters is needed in Pharma domain, but this time this comes from another necessity: it will improve significantly the quality of the tablets, resulting in a more efficient product in terms of dissolution properties related to the thickness of the coating. These simple examples are explanatory of the similarity between domains. Often the criticalities, and thus the needs, are common only for two domains, but sometimes also for all of them. However, the approach provided by CAPRI helps the companies to have a standard path for the development of the Cognitive Solutions, thus a standard way to face the critical activities that need to be improved. This common way to operate will definitely fosters the collaboration even across domains, leveraging on the shared needs.

Regarding the Business areas, CAPRI project is expected to improve mostly the maturity level of “Production management”, “Quality management” and “Maintenance management”. The Cognitive Solutions proposed by the partner are concerning mainly these three areas. Production, as already discussed, will be deeply affected by the introduction of the CSs, thus a significant step ahead in this Business area is expected. Quality management is influenced by several CS that will be developed. In particular, real-time monitoring and parameters adjustments will improve the overall quality of the products. For instance, this aspect is well represented by the Pharma domain, which will develop a specific CS to improve the tablets quality. Lastly, Maintenance management is expected to improve for the same reason of Quality management. Several CSs that will be developed in WP3 will concern this aspect. Some of them indirectly, others instead have as main object to improve the maintenance of physical assets. For these reasons, a significant leap should be done by the end of CAPRI project in this Business area.

5 6Ps Validation and Results

As presented at the beginning of this document, 6Ps digital transformation tool aims at helping companies in generating strategies for approaching and moving forward Industry 4.0. It serves as a starting point and a basis for new ideas and roadmaps during a digital transformation process.

As for Industry 4.0 Test, it has been decided to focus the attention on CAPRI’s industrial pilots. They represent the practical use cases of the project and they operate among three different sectors:

- **Asphalt**
- **Pharma**
- **Steel**

After having measured their digital maturity level using Testi4.0 online survey, now it is interesting to assess their AS-IS practical status about I4.0 technologies implementation and their desired TO-BE

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outcome when the project will be finalized. It is important to put in light the gaps necessary for reaching the desired goals. As already explained, both the tools aim at fostering digital transformation, but 6Ps methodology proposes more concrete solution and for this reason it needs to be used as a complementary instrument a side the first one, TestI4.0.

In the following paragraphs have been summarized the results collected from the three project's use cases: EIFF (Asphalt), AMS (Pharma) and SID (Steel).

It is important to mention that the survey was not conducted only by the pilots but also research institutes collaborating with them have been involved. To be precise, CARTIF has complemented EIFF interview in Asphalt domain; RCPE has complemented AMS interview in Pharma domain. The research institutes perspective contributes to give meaning to the *state of the art* of the industry in which the pilots are operating and in the expected innovation after CAPRI project's end.

According to the 6Ps methodology, for each pilot, after the online 6Ps (self-assessment) survey, a further interview has been conducted with the aim of checking coherence in pilot's answers and more in general to collect clarification about the given results. Final outcomes have been reported in following paragraphs.

5.1 Asphalt Industry (EIFF)

Eiffage Infraestructuras (EIFF) is one of Europe's leading operators in construction and concessions. The company, with 72,500 employees works in construction, real estate, urban development, civil engineering, metallic construction, roads, energy systems and concessions. Inside CAPRI project, it represents the pilot related with **Asphalt Industry**.

Regarding the Asphalt domain, also Cartif (CAR) has participated to the 6Ps self-assessment as first and to the face-to-face interview as second, but covering the role of technology provider, the survey has been only partially compiled, providing their point of view about the industrial process. Not all the 6 pillars have been covered, so in the presentation of results, Cartif's answers are handled as complementary to Eiffage's ones and only answers from the pilot are reported.

As already outlined, the digital maturity assessment is focused on 6 different areas and so, results reflect this structure. Anyway, it is possible to provide a general maturity level, taking into account all the dimensions aggregated together.

In the Asphalt domain, the current digital maturity level is about 1.5 (between INITIAL and MANAGED level) and CAPRI project is expected to drive it to an average level of 2.4 (between MANAGED and DEFINED).

The following radar chart shows the overall set of answers provided and discussed by EIffage.

To make the graph more readable, names of pillars and dimensions have been omitted, but they are easily understandable: the 6 pillars are numbered as follow and highlighted in different colours:

1. Product (Red)
2. Process (Orange)

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3. Platform (Yellow)
4. People (Green)
5. Partnership (Light Blue)
6. Performance (Blue)

For each pillar, all the answers related to the six (or more) dimensions are reported and they are numbered according to the descriptions in paragraph "The 6Ps digital transformation journey and its dimensions".

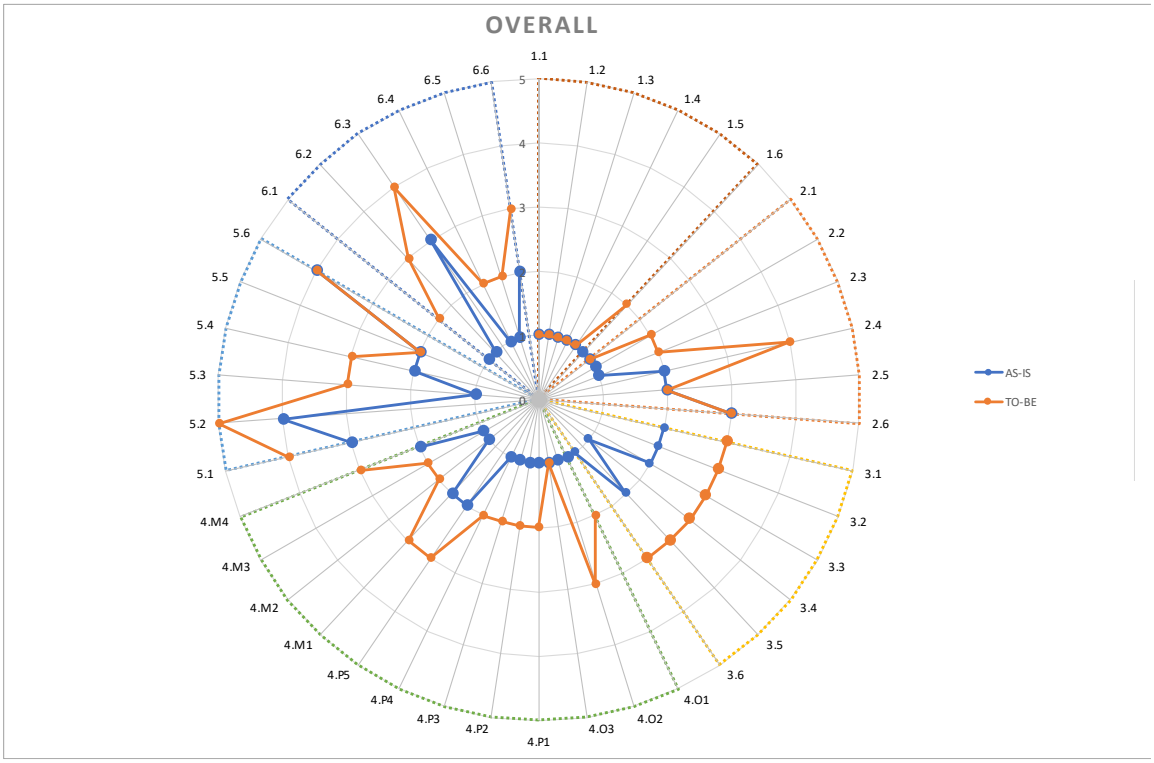

Figure 15 - EIFF 6Ps overall answers

The blue line represents the AS-IS situation, the orange one the TO-BE, that is, the expected status after CAPRI project (of course, the orange line is always positioned at the same level or above the blue one).

5.1.1 Product Outcome and Graph

Speaking about *Product* pillar, as it is visible from the radar chart below, EIFF doesn't expect a great improvement form the CAPRI's project.

All dimensions are set to level 1 as AS-IS level and the only improvement is foreseen for the "business models enabled by the product" dimension, where it is expected the possibility to put in place a consulting service regarding the product and not to base the revenue system simply just on the product's sales, as it happens now.

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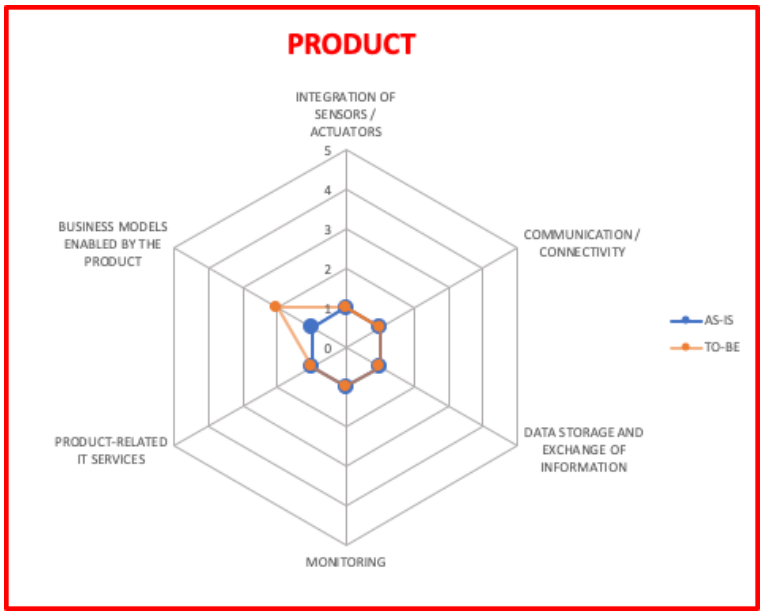

Figure 16 - Eiffage Product Radar Chart

Precisely, the interviewed explained that inside asphalt products no sensors will be integrated, the product has not communication interfaces, no IT services are correlated to the product and they will be not included at the end of the project. So, it makes sense to expect a transition of the product digital maturity only considering the "Business models enabled by the product". So, clearly, the expected improvement about the Product's maturity level is not as much relevant: it starts from an average level of 1 to an average level of 1.16.

5.1.2 Process Outcome and Graph

About the *Process* pillar, it is expected a shift regarding

- "Production" and "Quality Management" dimensions, where it is foreseen a one-step jump, connecting production processes via different channels and protocols and putting in place a diagnostic quality system. In both case, one of the direct consequence will be a reduction of the human effort
- "Maintenance management" dimension, where it is expected a two-steps jump and the transition will be driven by the adoption of predictive models in the maintenance activities.

On the other side, no improvement is desired regarding "Design and Engineering", "Supply Chain Management" and "Logistic Management" dimensions:

- "Design and Engineering" is expected to remain stuck at the lowest level, since currently there isn't any plan to develop a digital model of the production process
- "Supply Chain Management" is already placed in a middle level, meaning that the process is monitored and partially integrated and automated
- In "Logistic Management", the human effort is expected to remain still very present, supported only occasionally by digital tools.

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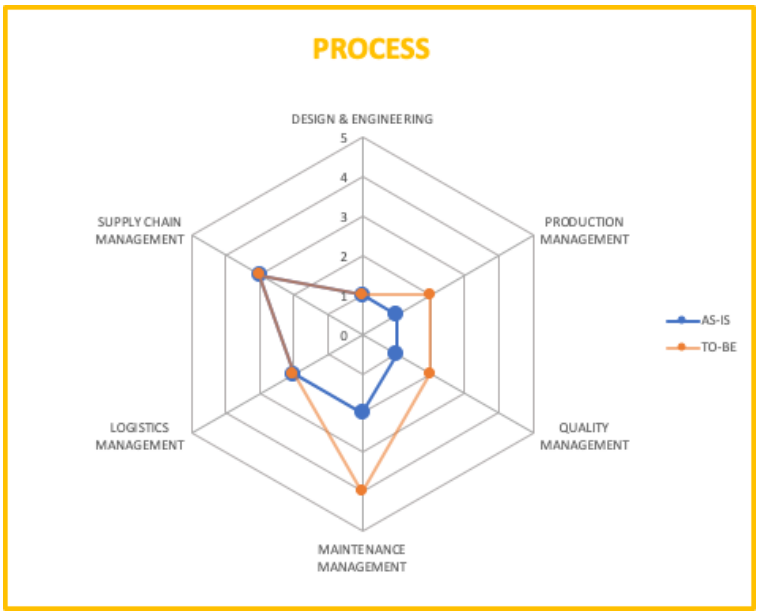

Figure 17 - Eiffage Process Radar Chart

Actually, cognitive solutions designed in CAPRI project are strongly driven by: the need of improving the process in order to guarantee a better quality of the final product and the need of putting in place a predictive maintenance system to save cost and time in the baghouse.

Moreover, since to reach the highest levels about Production and Quality Management there are lot of parameters to be taken into consideration and CAPRI sensors cover only a subset of them, it is not expected to reach a full transition regarding them.

The radar chart above reflects precisely these aspects.

On average, it is foreseen a transition from 1.7 (between INITIAL and MANAGED) to 2.3 (little more than MANAGED).

5.1.3 Platform Outcome and Graph

Analysing the *Platform* pillar, you can see from the radar chart below that the current situation fluctuates between level 1 and 2, while the foreseen situation is represented in a very symmetric shape: all dimensions are planned to get level 3 (DEFINED).

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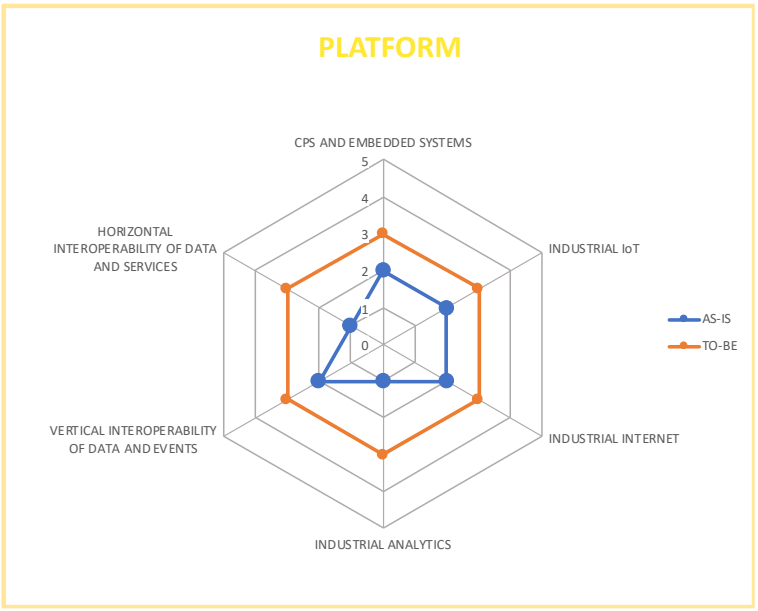

Figure 18 - Eiffage Platform Radar Chart

The two-steps jump in Industrial Analytics (moving toward a situation where analytics models are in place and constantly verified and validated by real word data) is perfectly understandable considering the large amount of data provided by new sensors developed in CAPRI.

But in general, all the other expected transitions are in line with CAPRI's purposes since the design of the cognitive solutions perfectly matches with a generalized level 3 in the digital manufacturing platform.

Summarizing, starting from an average level of 1.7 (between INITIAL and MANAGED), the expected one is level 3 (DEFINED).

5.1.4 People Outcome and Graph

About *People* pillar, for sake of clarity, results are analysed according to the three sub-pillars: operator, engineer, manager.

- From the operator point of view, it is not foreseen any transition regarding the "smart product", coherently with what was said about Product pillar: the product itself is not expected to be "digitally" improved and so, neither skills and experiences related to it. On the other side, the introduction of analytics models and new sensors will require to increase corresponding competencies and this explains the expected improvement in "smart supply chain" and "smart operation"
- From the engineer point of view, all dimensions are expected to jump one step ahead, including the "smart product". Indeed, introducing sensors in the process, it is possible to monitor the whole lifecycle of the product and so, it will become fundamental to share such awareness among people carrying out monitoring tasks.
  Actually, by the self-assessment survey the dimension "Industry 4.0 Infrastructure" was originally planned to remain stuck at level 1, since no development of modelling languages and programming tools are in charge to Eiffage. But we have agreed together that at the end of the project, EIFF will for sure benefit of Cartif heritage.

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- From the manager point of view, all dimensions are expected to jump one step ahead. In particular, coherently with CAPRI project view, also “Industry 4.0 strategy” will be affected: the expectation is to create a strong leadership able to define and manage a strategic approach in order to drive the company toward the consolidation of Industry 4.0.

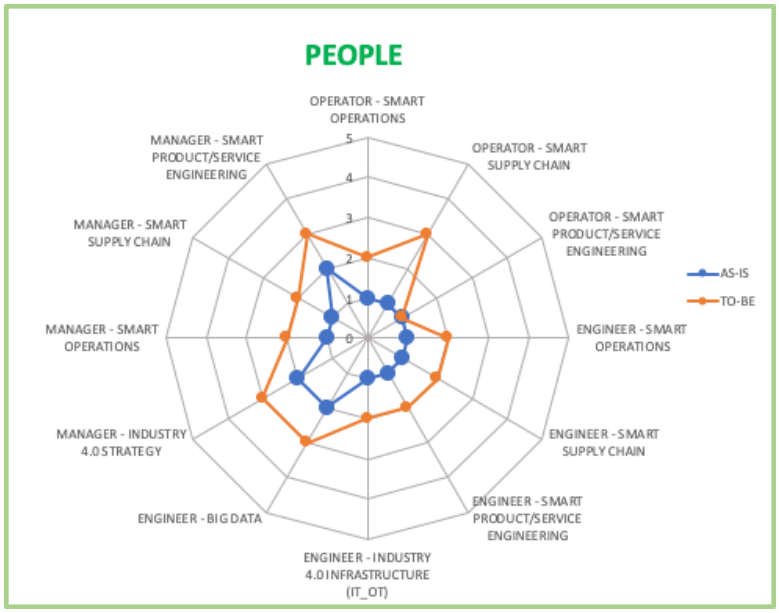

Figure 19 - Eiffage People Radar Chart

Generally speaking, with the only exception of “Operator– Smart Product”, all dimensions are expected to reach level 2 or above.

According to Eiffage, the large amount of data generated by new sensors combined to data already existing (but never taken into consideration before) could represent a strong incentive to share the digital culture among workers (of all level).

On average, it is expected a transition from level 1.3 (little more than INITIAL) to level 2.3, meaning that a full transition over MANAGED level is foreseen.

5.1.5 Partnership Outcome and Graph

Regarding the *Partnership* pillar, the radar chart below shows an expected improvement for almost all dimensions: the average shift is from level 2.3 to level 3.2, so a full transition to the DEFINED level is expected.

However, “supplier” and “customer” dimensions won’t be involved by the development of the cognitive solutions.

Since the project is not related to supplier and logistic aspects (for example, in *Process* pillar we already outlined that both the AS-IS and TO-BE levels for “Logistic Management” dimension are set to 2), also the “Supplier” dimension in *Partnership* pillar is not expected to improve.

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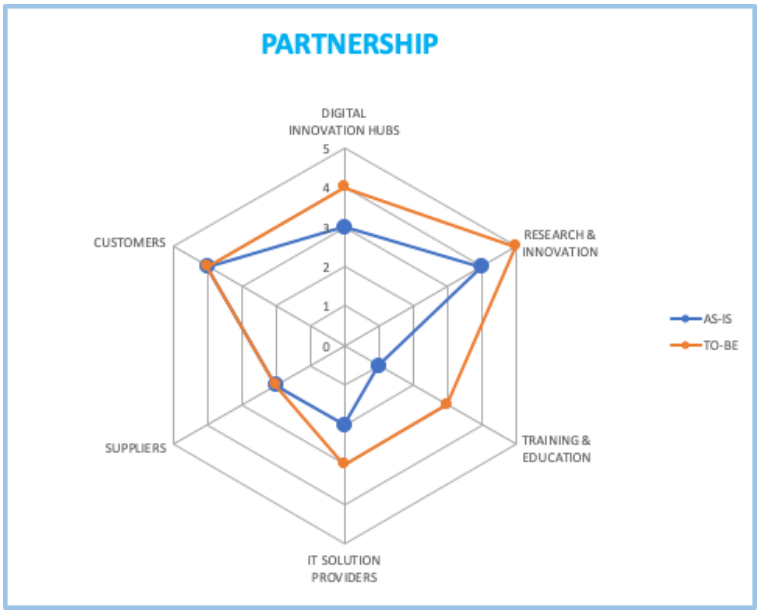

Figure 20 - Eiffage Partnership Radar Chart

On the other side, both “Research and Innovation” and “DIHs” dimensions are planned to reach a very high level of digital maturity (starting in both cases already from a good position). In particular, thanks to CAPRI’s contribution, the first one is expected to get the maximum level, foreseeing a systematic participation to research and innovation programs/events.

It is still not perfectly clear which level embodies the current and expected digital maturity of “training and education” dimension: for sure, new solutions developed in CAPRI will require to implement courses to train workers. But since the educational aspect is not clearly included in the cognitive solutions requirements but they are direct consequences, at this stage it is not possible to foreseen if “Competence assessment, training and education programs will be done regularly” as level 3 states.

5.1.6 Performance Outcome and Graph

Analysing the *Performance* pillar from the radar chart below, it emerges that it is expected a one-step transition for all dimensions, with the only exception of the “economic” one, planned to move from level 1 to level 3.

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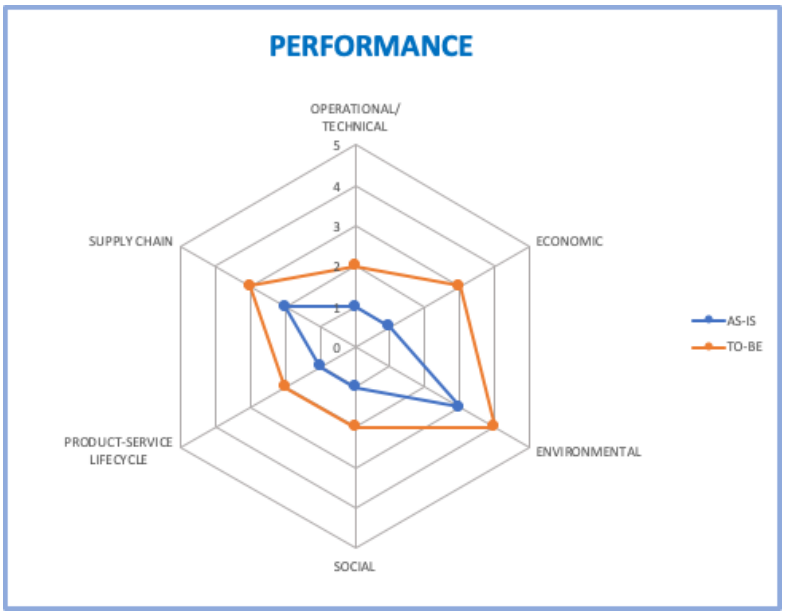

Figure 21 - Eiffage Performance Radar Chart

On average, it is foreseen an improvement from level 1.5 (exactly in the middle of INITIAL and MANAGED one) to level 2.7 (close to the DEFINED one).

For sure, increasing the amount and the quality of available data, deploying also a platform to manage them, is the base to implement a structured system of performance indicators in several areas.

“Operation/technical”, “social” and “product/service lifecycle” KPIs are currently not calculated, but within the end of the project they are planned to be measured in order to be able to perform at least a retrospective analysis over the trend.

“Economic” and “supply chain” KPIs will be not only measured, but will be useful to implement a diagnostic system to attempt to understand causes affecting events.

The highest level in this area is expected to be reached by the “environmental” dimension, foreseeing to include predictive KPIs analysis. Actually, one of the key topic of CAPRI project is the environmental sustainability, that can be obtained (in asphalt domain) by reduction of energy and fuel consumption and recycle of raw materials. Hence, it is reasonable that a big effort will be spent to improve the methods of traceability and measurement of performance KPIs related to environmental area.

5.2 Pharma Industry (AMS)

Applied manufacturing Science (AMS) is a privately specialised company in applying advanced manufacturing science and it is located in Poznan, Poland. AMS’s teams consist of highly-trained professionals from the pharmaceutical industry and research. Inside CAPRI project, AMS represents the pilot committed with Pharma Industry.

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Regarding the Pharma domain, also RCPE has participated to the 6Ps self-assessment as first and to the face-to-face interview as second, but covering the role of research institute, the survey's results are not focused on providing an effective overview of the production process.

So, in following paragraphs, RCPE's answers are handled as complementary to AMS and they are reported mainly AMS's results.

Reflecting the same structure of the Asphalt domain, results are reported according to the 6Ps pillars but we have taken into account also an aggregated view of the dimensions.

In the Pharma domain, the current digital maturity level is about 1.3 (slightly above INITIAL) and CAPRI project is expected to drive it to an average level of 2.3, that is, it is expected a full transition from INITIAL to MANAGED.

The following radar chart shows the overall set of answers provided and discussed by AMS.

To make the graph more readable, names of pillars and dimensions have been omitted, but they are easily understandable: the 6 pillars are numbered as follow and highlighted in different colours:

1. Product (Red)
2. Process (Orange)
3. Platform (Yellow)
4. People (Green)
5. Partnership (Light Blue)
6. Performance (Blue)

For each pillar, all the answers related to the six (or more) dimensions are reported and they are numbered according to the descriptions in paragraph "The 6Ps digital transformation journey and its dimensions".

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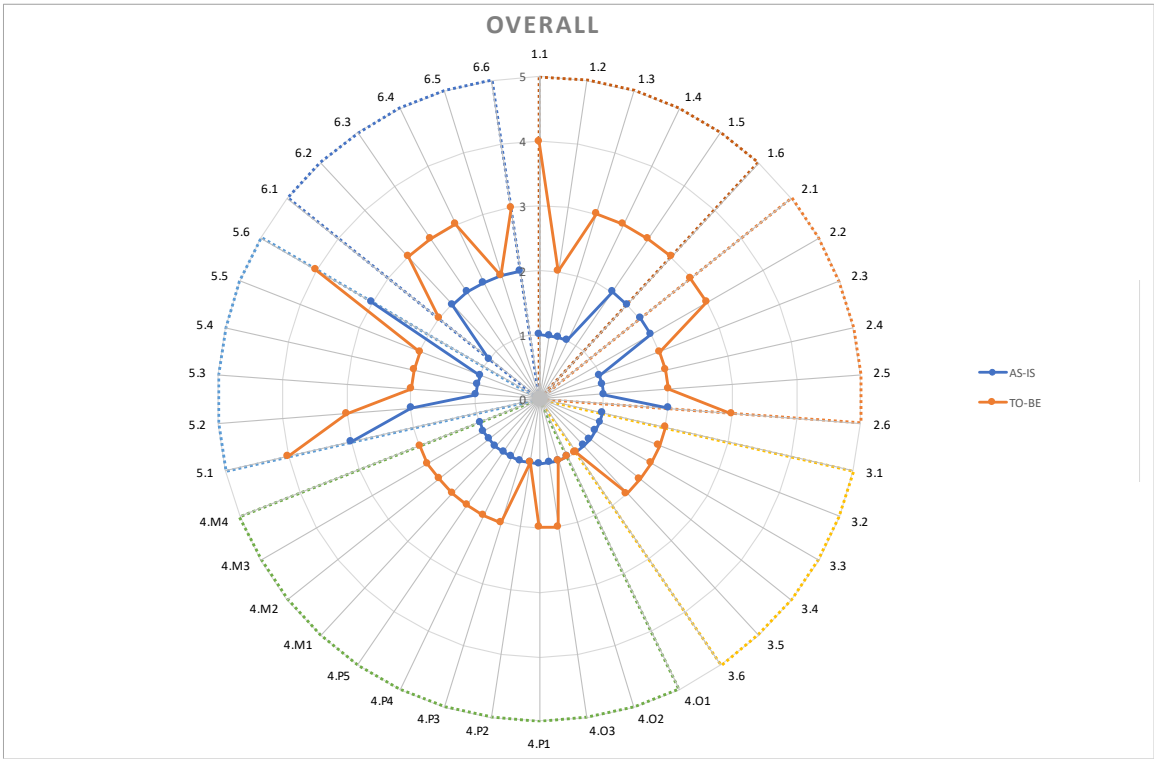

Figure 22 - AMS 6Ps overall answers

The blue line represents the AS-IS situation, the orange one the TO-BE, that is the expected status after CAPRI project (of course, the orange line is always positioned at the same level or above the blue one).

Differently from the other domains (Asphalt and Steel), Pharma is expecting to improve all the 6 dimensions (Product included); furthermore, for most of them it is expected a quite big leap, which is the coherent to CAPRI project's aims.

5.2.1 Product Outcome and Graph

Talking about the *Product* pillar, also in this case the solutions developed in CAPRI project are not sensors directly embedded in the product. Indeed, they are solutions mostly focused on process improvement, in order to guarantee a better quality of the final product, a reduction of human effort, a reduction of costs related to waste of material, plant's failure… So, it is not very interesting to talk about digital maturity related to the physical product.

Moving apart from CAPRI's purpose (strictly focused on tablets), the product categories vary to a great extent of types and include, for instance, packaging and hybrid products, such as, the combination of product and App.

In this case, it makes sense to talk about product digital maturity.

So, if we extend the concept of product, including also the PSS (Product System Service) in general, hence, in the pharma domain in following years it is expected a great improvement: on average the foreseen transition goes from 1.33 (slightly above the INITIAL level) to 3 (exactly DEFINED level).

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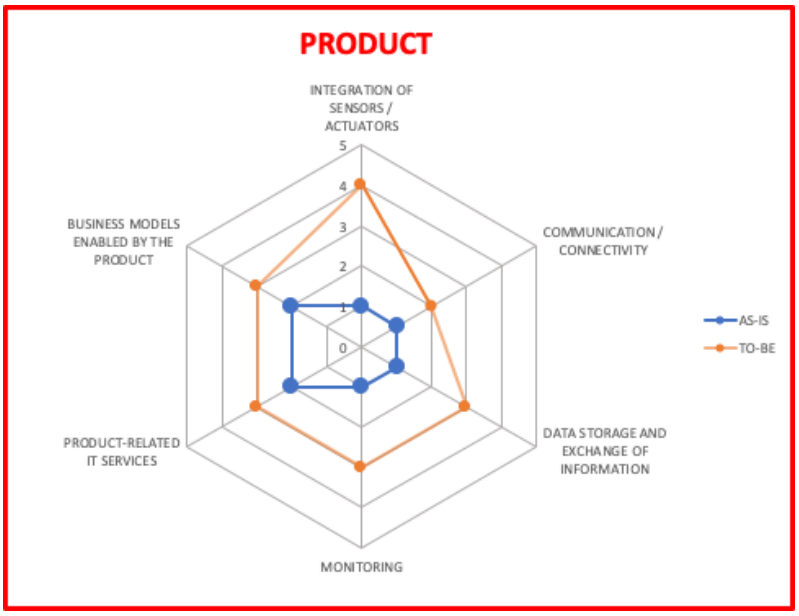

Figure 23 - AMS Product Radar Chart

The highest jump regards “integration of sensors/actuators” dimension: starting from a situation where it is not made use of sensors and operators inspect product’s features by hand, it is planned to reach a status where sensors are perfectly integrated with the product and human effort is strongly reduced. Of course, sensors embedded inside the product will generated a large amount of data, providing consequently more detailed information and supporting the monitoring activity.

5.2.2 Process Outcome and Graph

Process pillar expects a smooth (and symmetric) transition from a balanced INITIAL/MANAGED level to a balanced MANAGED/DEFINED level: each dimension is planned to move a step ahead. On average, the AS-IS maturity level of 1.5 will reach the TO-BE value of 2.5.

This linear shift is in line with the project activities, and there are not drastic changes.

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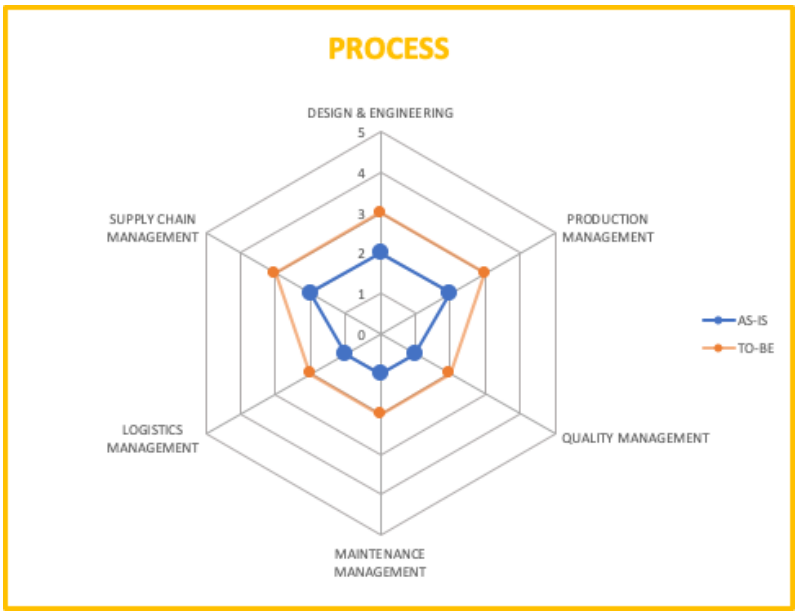

Figure 24 - AMS Process Radar Chart

The interview revealed how the partner is willing to move from a "paper-based" production process, that needs documents and instructions written by the highest levels of the chain, to a standardised and more efficient system, that will cover the gap between production and development. Thus, saving time and money. Moreover, some processes that now are carried out in an off-line way will be performed on-line, such as the thick coating estimation. This specific task, fundamental for the quality of the product, will definitely improve the efficiency of the process and assure a higher quality rate of the process outcomes.

This transformation is led by the holistic view that the AMS partner desires to have of its production system, from how a product is developed to how it is manufactured. Indeed, two out of three dimensions that will increase to the middle level are "design & engineering" and "production management", which again prove to be the areas in which AMS is putting its effort to improve and transform towards a more digital maturity.

The third one is "Supply Chain Management", whose transformation is driven by the need of automating repetitive and structured process (similarly to "production management").

5.2.3 Platform Outcome and Graph

The pillar *platform* it the third pillar assessed by the 6P tool. The AS-IS condition is at its lowest possible state, the INITIAL level for all dimensions. Despite it is hard to identify a specific reason why the actual level is so low, from the interview carried out with the expert it came out that the pharma industry is really committed when dealing with data and information. This is due to the strict regulations and standard that a pharma company has to respect and follow. This is probably one key aspect that influenced the upgrading of the platforms in terms of sharing and collecting useful information.

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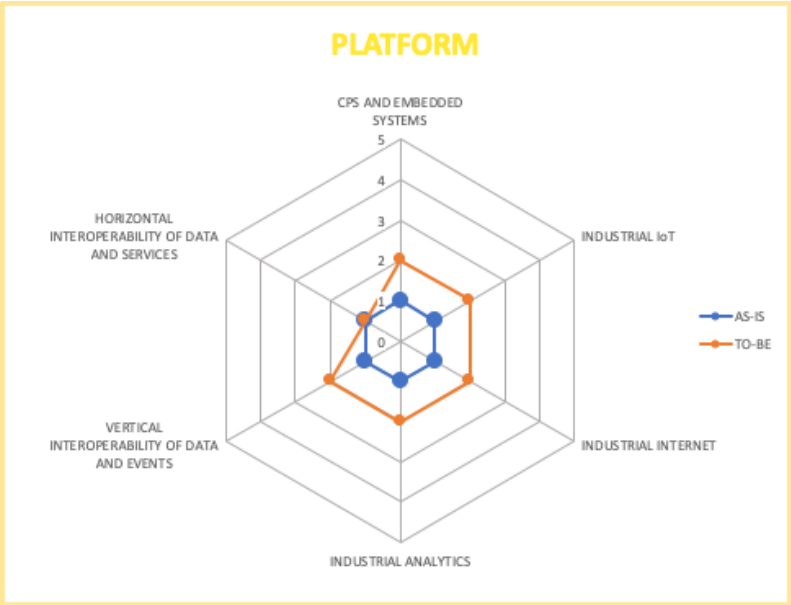

Figure 25 - AMS Platform Radar Chart

Despite the strong limitations aforementioned, external to the company, the improvements in the *process* pillar, as well the *product* pillar, will allow to have new kind of data available, and thus the related dimensions are expected to improve.

Hence, the journey toward the adoption of a digital manufacturing platform will start implementing basic systems able to capture, store and analyse data from real world.

At the end, from a quite low maturity level of the AS-IS equal to 1 for all dimensions, the pillars at the TO-BE state, will reach on average the value of 1.8.

5.2.4 People Outcome and Graph

About *People* pillar, the current situation is a general level 1 for all dimensions: at each position of the working chain, the starting point is a reality where only basic software and technologies are used and AI competencies and skills are not required. Also, the "big data" dimension is approached at the lowest level, meaning that data are collected but not exploited.

Regarding the TO-BE situation, for sake of clarity, results are analysed according to the three sub-pillars: operator, engineer, manager.

- From the operator point of view, it is not expected any improvement regarding "smart operations" and "smart supply chain", coherently with the cognitive solutions developed in CAPRI. Instead, it is foreseen an improvement on "smart products" side, due to the adoption of 3D printing.
- From the engineer point of view, all dimensions are expected to reach level 2, implying the need of improving skills and competencies in managing data (and tools correlated to data). The only exception is "smart supply chain", for which the use of common software (for example Excel) still remain the main one.
- From the manager point of view, all dimensions are expected to reach level 2, implying the need of improving skills and competencies in managing data. In particular, it is expected to move first steps toward the adoption of Industry 4.0 ("Industry 4.0 strategy"), perfectly in agreement with CAPRI purpose.

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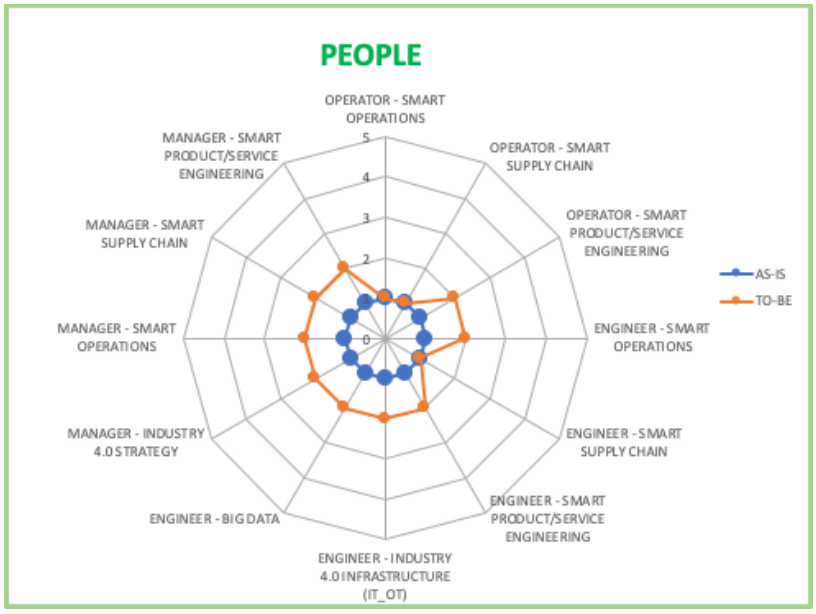

Figure 26 - AMS People Radar Chart

Summarizing, for sure an improvement is foreseen, since CAPRI cognitive solutions can work only if a standardization system is put in place. And standard means training course for workers in order to make them understand which standards have been adopted and how to manage them.

But the transformation won't be so radical.

Aggregating the results, it is expected to move from level 1 to an average level of 1.75, that is, it is expected an improvement but not to reach a full transition from INITIAL to MANAGED.

5.2.5 Partnership Outcome and Graph

The pillar *partnership* regards the network created by the company and of course, it is influenced by having joined CAPRI project. For example, collaboration with digital innovation hubs and digital ecosystem is here assessed in order to then provide support in its enrichment. The AS-IS level of the *partnership* pillar can be divided in two main parts: the first is less mature and the other includes dimensions having already reached a medium maturity level ("customers", "digital innovation hubs" and "research & innovation"). This unbalanced starting point is clearly determined by the core business of AMS, which provides advanced solutions for manufacturing in health and pharma sector.

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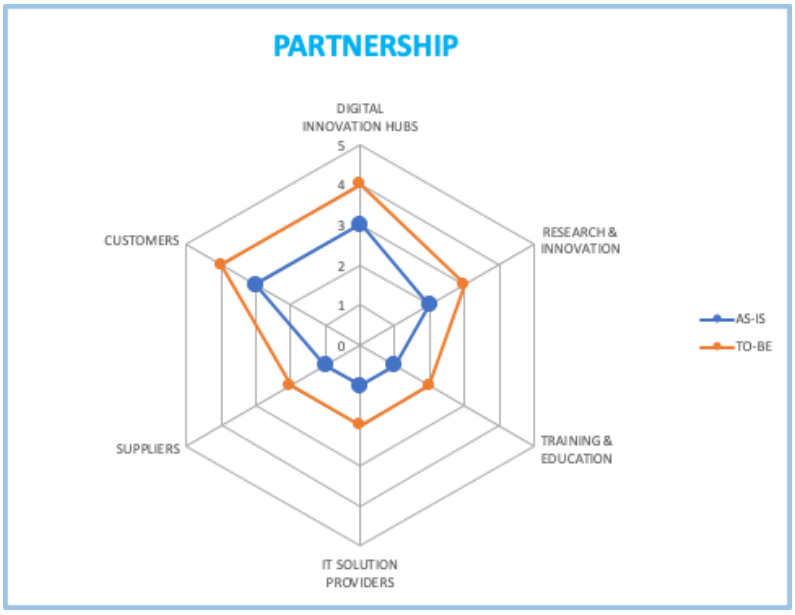

Figure 27 - AMS Partnership Radar Chart

It is interesting however to notice how the already advanced dimension such as “customers” and “digital innovation hubs” will further improve thanks to the collaboration enhanced by CAPRI project. The strict collaboration with the partner RCPE for the developing of most of the proposed Cognitive Solution, as well as membership in CAPRI, are surely key enablers of this transition.

Moreover, also a slight improvement will involve the less advanced dimensions, due to the overall effort that CAPRI requires in implementing the proposed solutions.

The average of the maturity will move from the AS-IS 1.8 to the TO-BE 2.8.

5.2.6 Performance Outcome and Graph

The last assessed pillar is the *performance* one. The aim is to support the adoption of digital business models and data/platform economy. All the dimensions will see a one-step improvement; the only exception is the “product-service/lifecycle” dimension. Generally, the dimensions are balanced both in the AS-IS state as well as the TO-BE.

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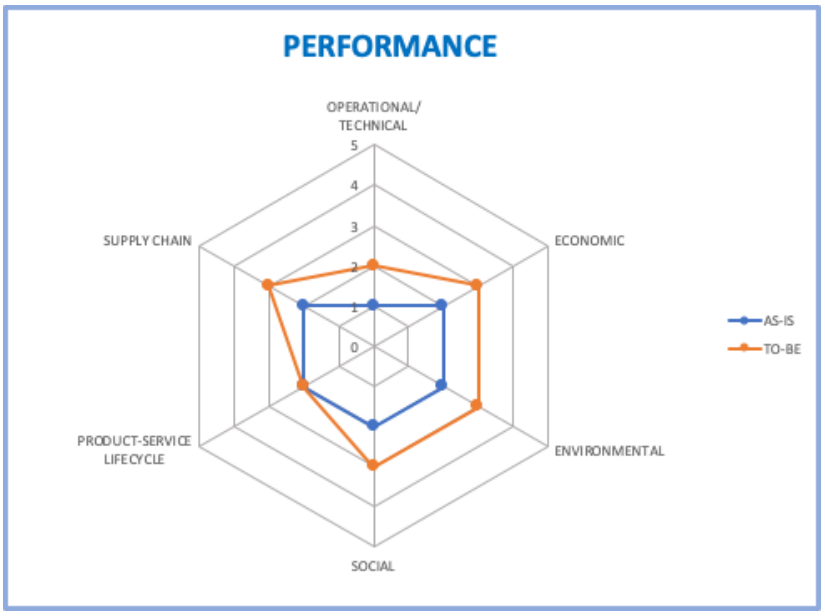

Figure 28 - AMS Performance Radar Chart

The interview revealed that the partner has already some clear improvements that is willing to achieve, such as the better management of the dust generated during the drugs processing. To measure performance improvement, it is required to put in place an efficient system of KPIs monitoring: for four among six dimensions ("economic", "environmental", "social" and "supply chain") related KPIs are planned to be used in diagnostic analysis, in order to be able to understand causes that affect behaviors.

"Operational/technical" and "product service lifecycle" KPIs will be monitored but only to perform retrospective analysis.

Overall, the average of the maturity will move from the AS-IS 1.8 to the TO-BE 2.6.

5.3 Steel Industry (SID)

Sidenor (SID) is a steel company leader in European steel industry for the production of special steel long products. It is also an important supplier of cold finished products in the European Market. Inside CAPRI project, SID represents the pilot committed with **Steel Industry**.

Reflecting the same structure of the Asphalt and Pharma domains, results are reported according to the 6Ps pillars but we have taken into account also an aggregated view of dimensions.

In the Steel domain, the current digital maturity level is about 2.4 (fully reached the MANAGED position) and CAPRI project is expected to drive it to an average level of 2.9, that is, very close to DEFINED position.

The following radar chart shows the overall set of answers provided and discussed by AMS.

To make the graph more readable, names of pillars and dimensions have been omitted, but they are easily understandable: the 6 pillars are numbered as follow and highlighted in different colours:

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1. Product (Red)
2. Process (Orange)
3. Platform (Yellow)
4. People (Green)
5. Partnership (Light Blue)
6. Performance (Blue)

For each pillar, all the answers related to the six (or more) dimensions are reported and they are numbered according to the descriptions in paragraph "The 6Ps digital transformation journey and its dimensions".

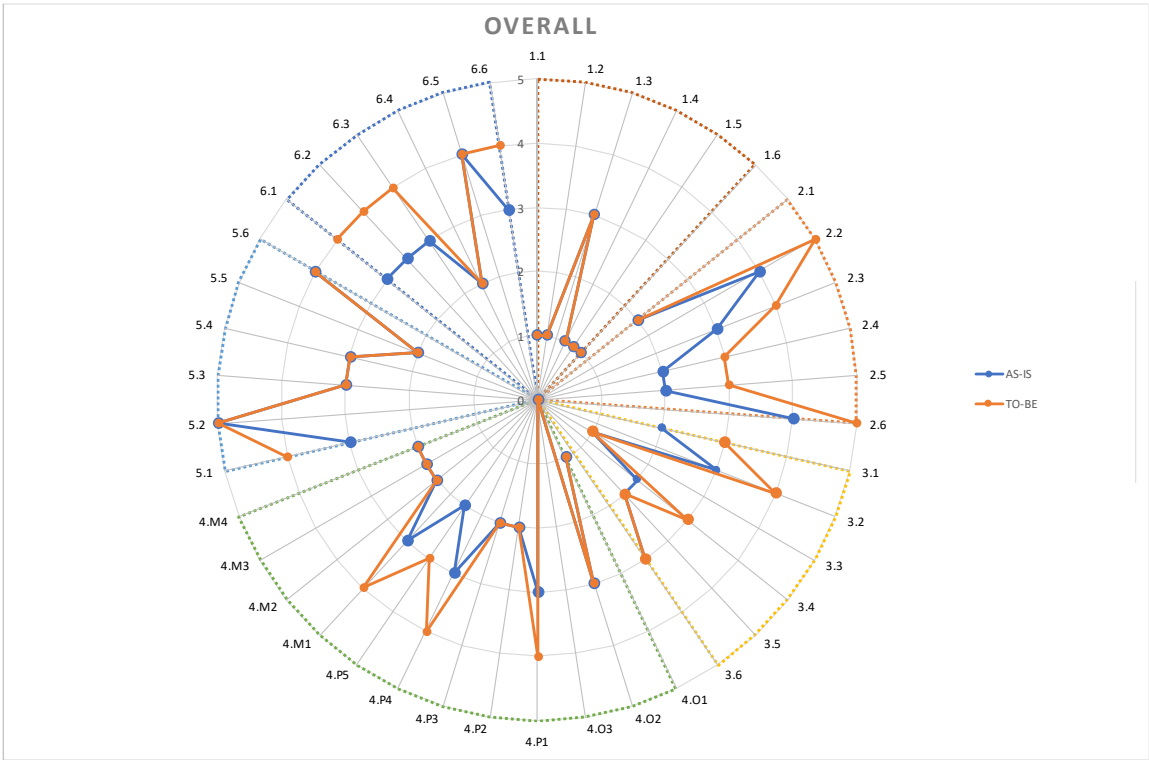

Figure 29 - SID 6Ps overall answers

The blue line represents the AS-IS situation, the orange one the TO-BE, that is the expected status after CAPRI project (of course, the orange line is always positioned at the same level or above the blue one).

It is interesting to notice that SID starts from a quite high level (if compared with the other pilots) and in terms of digital maturity, it is not expected a big leap ahead. It is important to take into consideration that the company has already become aware of the potential of finalized the digital transformation to be competitive in the market, so its journey started before CAPRI.

5.3.1 Product Outcome and Graph

Looking at the graph, it is visible that SID doesn't expect an improvement during CAPRI's project. In fact, the orange line related with the TO-BE state exactly covers the blue one. The reasons of this result, like for asphalt use case, are connected to the fact that the company will not produce a smart product. Indeed, the final product are steel bars (of different size and composition) to be reused by

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SID's customers for their purposes: at the end the product is completely transformed, so it is no compatible with the integration of sensors.

Then, looking at the "storage and exchange information dimension", has been recorded a level 3, that's because the product has been already connected to passive data stores.

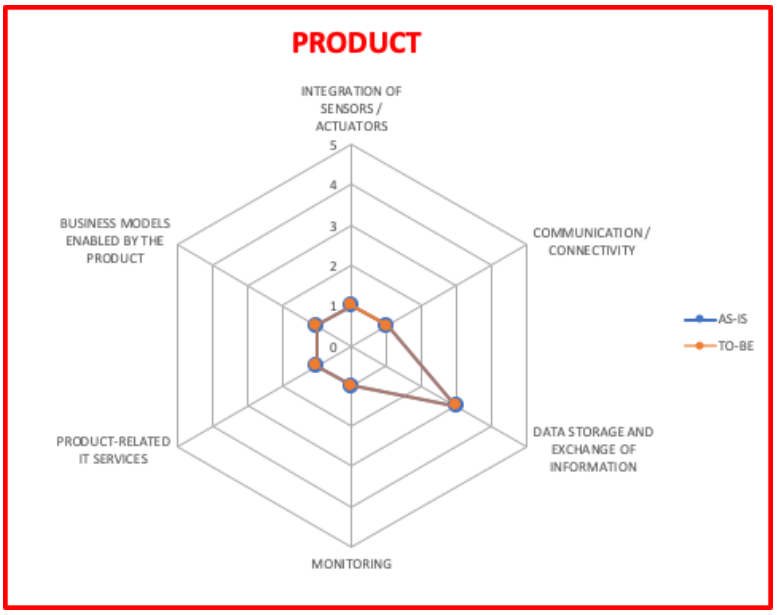

Figure 30 - SID Product Radar Chart

The only dimension presenting a medium level of digital maturity is "storage and exchange information dimension", since traceability of bars during the production process, generated lot of data. Actually, SID already has in place a system to generate large amount of data; however, data are not exploited and the purpose of CAPRI is to leverage on those data to implement the digital twin.

On average, the AS-IS and TO-BE maturity level is 1.3.

5.3.2 Process Outcome and Graph

Speaking about the *process* pillar, the company already has a good level of innovation and foresees a light improvement in almost all business processes.

The only exception is the "design & engineering" dimension: the company will keep using the actual preliminary digital models for representing the process. Indeed, there isn't any interest for the company to apply changes the design of steel bars since it isn't a task that can benefit from digital transformation.

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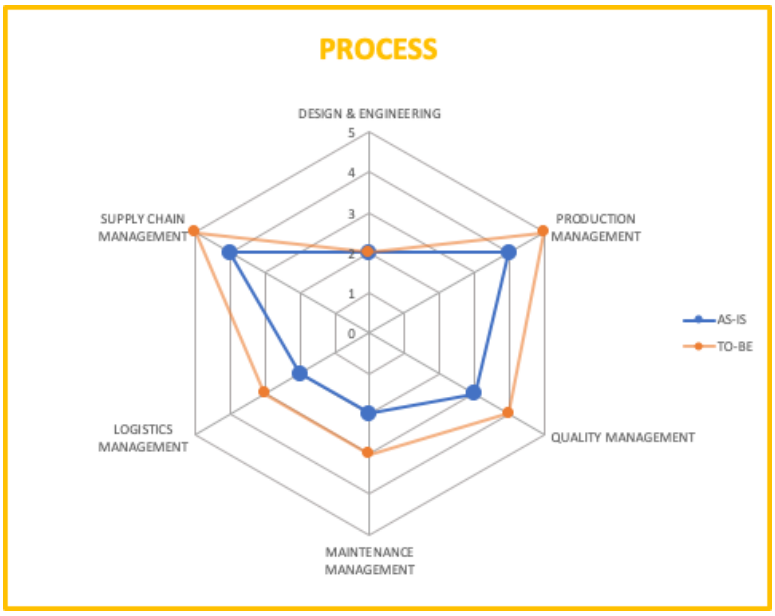

Figure 31 - SID Product Radar Chart

"Production" and "supply chain management" are expected to reach the highest level, since both the processes will be systematically monitored and strongly automated, supported by a fast system of information exchange. In this case, the transition is fostered also by other research activities already in place, and in fact also the starting level is quite high.

Also the improvement expected in "logistic management" area won't be driven by CAPRI cognitive solutions, but however within three years logistic process are expected to be partially automated.

On average, the company foresees to move from level 2,83 in the AS-IS state, to level 3,66 at the end of the project, showing to have already addressed its digital transformation.

5.3.3 Platform Outcome and Graph

Looking at the radar chart related to *platform* pillar, it is visible that SID foresees an improvement in three (out of six) areas, "Cyber Physical System" (CPS), "industrial IoT" and "industrial analytics".

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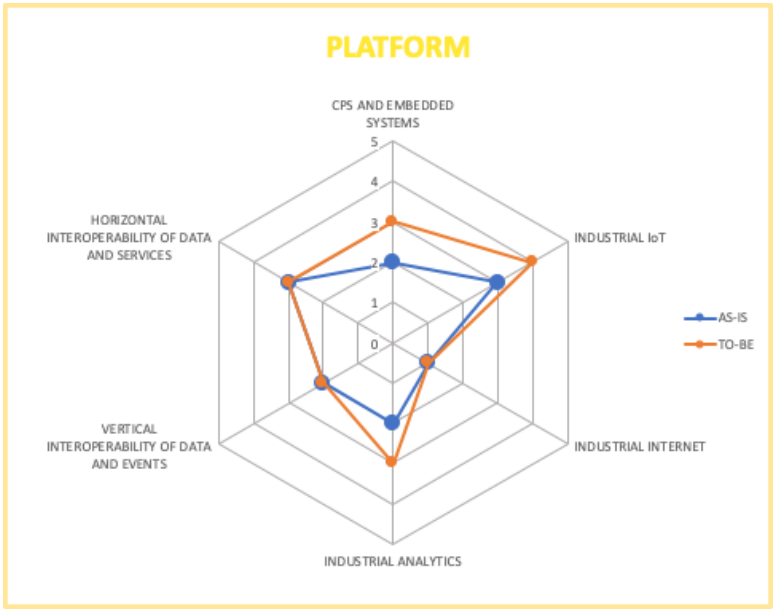

Figure 32 - SID Platform Radar Chart

The radar chart perfectly reflects the purpose of the company in CAPRI project: the implementation of digital twin solution (and the required installation of new sensors) will clearly imply

- The capability to integrate additional sensor to understand the ambient (CPS)
- The capability to govern and control sensors by dedicated hardware (Industrial IoT)
- The capability to model the system using simulation tool (Industrial analytics)

In particular regarding last dimension, it can't be excluded that the development of the digital twin will put the basis also to the implementation of forecast models, making Industrial Analytics to reach the level 4 of the digital maturity scale.

Despite what it may seems, the decision to not invest effort in improving "vertical interoperability of data and events", moving the data storage from an edge system to a cloud system is not due to a lack of digital maturity.

On the opposite, it is a decision driven by the company's data policy, that in order to reduce as much production blocks as possible relying on proprietary resources instead of shared storage system. And of course, this aspect is reflected also in the *People* dimension, since to manage autonomously data architecture, it is required to have specific competencies and skills.

On average, the company foresees to move from a level of 2.16 (MANAGED) in the AS-IS state, to level 2.66 (between MANAGED and DEFINED) at the end of the project.

5.3.4 People Outcome and Graph

About *People* pillar, the current situation starts from an average level of 2.3, showing again that in the company some expertise is already shared among people: indeed, the expected growth is low, moving to a TO-BE status of 2.6 on average.

Again, for sake of clarity, results are analysed according to the three sub-pillars: operator, engineer, manager.

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- From the operator point of view, the dimension “smart product” can’t be evaluated since none of the possible answer matches with the actual situation (also the lowest level, related to CAD design, is not applicable in this scenario).
  Regarding the other two dimensions (“smart operations” and “smart supply chain”), differently to what you can infer from the graph, it is expected an improvement in next years but not due to CAPRI. Indeed, the company is planning to adopt both wearable devices ang AGV, but since it is definitely not related to CAPRI, we have agreed not to take in consideration such enhancement.
- From the engineer point of view, three (out of five) dimensions are expected to improve and they are perfectly in line with CAPRI mission. Indeed, to introduce a formal approach to define and manage Industry 4.0 infrastructure and to re-design processes and operation to exploit Industry 4.0 technologies are driven pillar in the project.
  Of course, increasing available data via sensors installation and improving data management, also more qualified competencies regarding big data are required.
- From the manager point of view, three (out of four) dimensions are not expected to go through any transition. The only exception is “Industry 4.0 strategy”: the plan to build relationship among different stakeholder of the Industry 4.0 ecosystem perfectly matches with the approach described in previous sub-pillar.

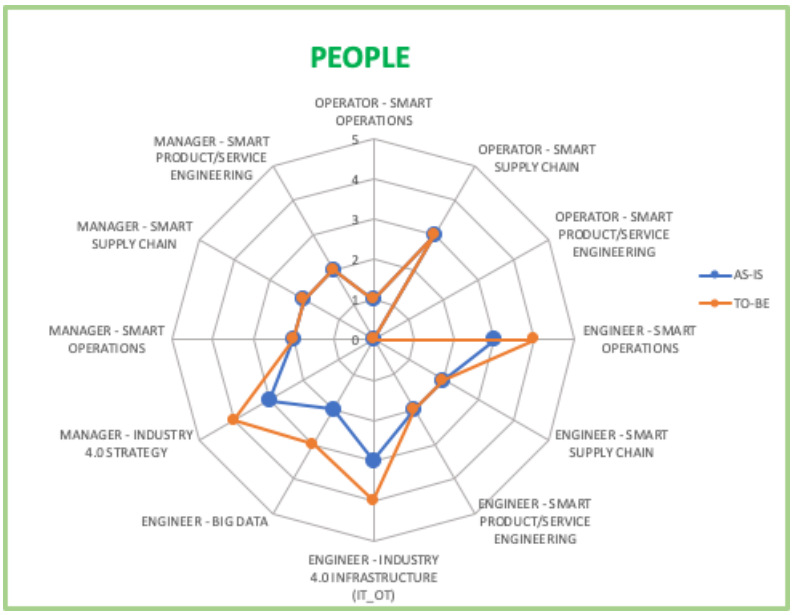

Figure 33 - SID People Radar Chart

5.3.5 Partnership Outcome and Graph

Regarding *Partnership* pillar, looking at the radar chart, immediately appears how SID, thanks to its long time in the field and further research and innovation projects still running or already concluded, is already quite well positioned in all areas of analysis.

In fact, the starting level is about 3.3 (that is, the DEFINED level is already fully reached) and the final one is on average 3.5: the AS-IS and TO-BE levels are quite the same.

At the end of the project, the company imagines to be more engaged with DIHs in mutual projects and initiatives and this is why it is expected an improvement in “digital innovation hubs” dimension.

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Competence assessment, training and education programs will be keep done regularly; participation to research and innovation programs is already systematic (CAPRI is an example); IT providers collaborations will continue in order to develop together reliable business solutions, so no transformation is expected.

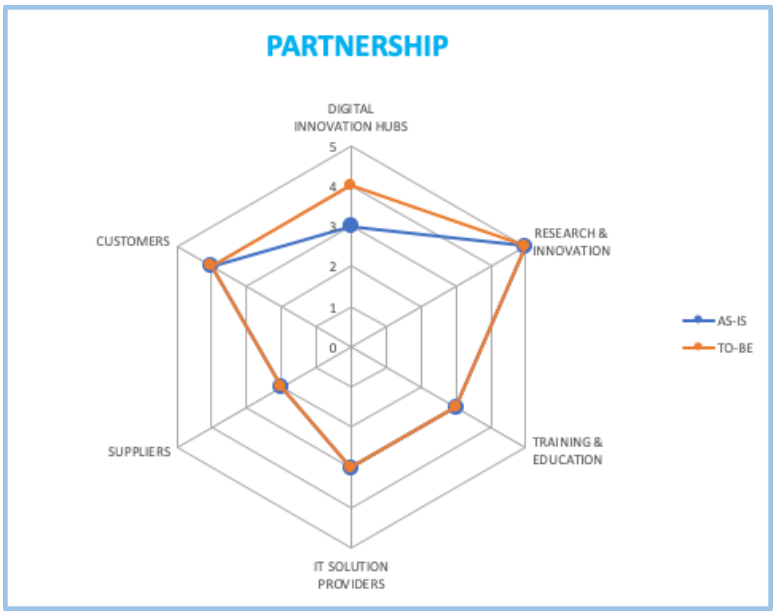

Figure 34 - SID Partnership Radar Chart

5.3.6 Performance Outcome and Graph

Finally, speaking about *performance* dimension, Sidenor foresees an improvement in almost all the areas. Operational, supply chain, economic and environmental KPIs won't be tracked only to perform diagnostic measurement but predictive analysis, together with statistical models and forecasts techniques, will be introduced.

Indeed, for those dimensions it is expected a transition from level 3 to level 4.

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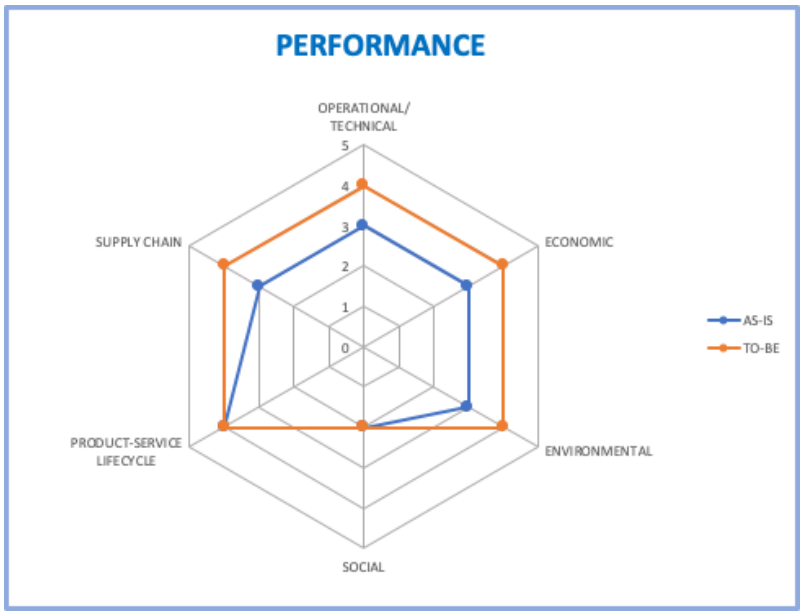

Figure 35 - SID Performance Radar Chart

To be precise, improving economic and environmental performances is one of the main goal of the company (reducing environmental impact is also a key pillar of CAPRI mission) and it is expected to be reached better understanding processes below. Of course, this will be feasible introducing new KPIs and tracking methods, supported by the increasing availability of data.

The "social" dimension will not register improvements mainly because it is not intrinsically included in the core of the project and, in the same way, "product – service Lifecyle" will not enlarge the scope of action keeping focusing the attention on life cycle cost (LCC) and environmental life cycle assessment (LCA).

5.4 Cross-domain Analysis in Process Industry

Comparing results provided by the three pilots in the 6Ps Digital Maturity Assessment, the first considerations that emerges are perfectly in line with what explained in the paragraph "Cross-Domain Analysis in Process Industry", where the comparison focused on Industry4.0 test result.

In the comparison it is important to keep in mind that there are several main goals shared among the pilots and also the way to reach them is agreed. Indeed:

- Final objectives are:
  - To reduce human effort in production
  - To reduce pollution and environmental impact
  - To improve quality of the final product
  - To save cost
- Solutions adopted to reach them are:
  - Implementation of Industry 4.0 (installing sensors to catch data)
  - Exploitation of data potential

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It is important to note that goals and solutions are not specific of the single domain but are sharable by different process industries. Hence, implementation of such solutions requires competencies and skills that go beyond the specific domain and this explains why the partnership pillar is located among the highest levels for all the pilots.

Moreover, the decision of adopting such solutions shows a shared awareness of the importance of data exploitation, strictly related to process monitoring. This explains why all the three pilots are investing lot of effort to improve how performance indicators are calculated: availability of a larger amount of data is meaningless if not elaborated and used in models, data visualization,…

Also the process area is expected to improve both for Asphalt, Pharma and Steel domain since the final objectives regard mostly the way how the product is realized, rather than the product itself. In fact, the "design and engineering" phase is not involved in the transformation.

Anyway, the final digital maturity level is not homogeneous among the pilots. With respect to the others, the Steel domain starts from an higher position in all pillars (with the only exception of *Product*, which is at the minimum level for all of them), while the Asphalt and Pharma domains presents on average a similar situation. Hence, also the expected maturity level reached by Sidenor is quite higher with respect to those planned by Eiffage and AMS, which are very similar.

6 Conclusion and Future Outlook

The implementation of the first two steps of the DT methodology showed that all use cases expected a good improvement from CAPRI project, on average, they expect to reach a 2,5 level of digital readiness, setting between a "*managed*" and "*defined*" level according the 6Ps digitalization journey nomenclature.

Thanks to industry 4.0 Tool and 6Ps model, EIFF, AMS and SID have been able to measure the current level of digital maturity of their business processes and to set the desired progress to be reached. Thanks to 6Ps model the companies have also in mind a way to succeeding in reaching the desired level marked.

Speaking about the future, inside CAPRI project, in WP5 both surveys will be done again in order to check the improvements recorded by the three industrial pilots, regarding the updated level of digital maturity reached and the progress along the digital transformation roadmap that will be set together with EIFF, AMS and SID in the coming months.

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