Co-funded by the Erasmus+ Programme of the European Union

619130-EPP-1-2020-1-FR-EPPKA2-CBHE-JP

Selection: 2020

KA2 – Cooperation for innovation and the exchange of good practices –
Capacity Building in the field of Higher Education

strENgtHening skills and training expertise for TunisiAN and MorocCan transition to industry 4.0 Era / ENHANCE

D1.2. Gap analysis between HEIs and industry 4.0 skills related to MPQ4.0

Deliverable Identifier	**D1.2**
Deliverable Date	**M8 – 15/09/2021**
Deliverable Version	**V 1.4 – 2022**
Deliverable Leader	**UCAR**
Deliverable participants	**All**
Dissemination Level	**Public**

Document Control Page

Title	Gap analysis between HEIs and industry 4.0 skills related to MPQ4.0
Version	V1.4 – 2022
Deliverable number	D1.2
Work-Package	WP1
Status	☐ Draft ☐ Under Review ☐ Under Update ☐ Accepted by the coordinator ☒ Submitted to the commission
Authors	Sabeur Elkosantini
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Peer Reviewers 1:	Saber Darmoul
Assigned Date	10/04/2022
Received Date	27/03/2022
Peer Reviewers 2:	Zied Ghrairi
Assigned Date	22/04/2022
Received Date	22/04/2022
Date of Delivery	14/09/2022
Dissemination level	☒ Public ☐ Confidential, only for ENHANCE Consortium (including EC) ☐ EU-Restricted

Version History

Version	Date	Description	Edited by
1.0	17/04/2021	Initial Version	Sabeur Elkosantini, Sonia Gabouj, Rami B.H. Kacem
1.1	25/08/2021	Draft for Consortium sharing	Sabeur Elkosantini, Sonia Gabouj, Rami B.H. Kacem
1.2	27/04/2022	Final Draft with integration of comments from reviewers	Sabeur Elkosantini, Sonia Gabouj, Rami B.H. Kacem
1.3	27/04/2022	Final Version	Sabeur Elkosantini, Sonia Gabouj, Rami B.H. Kacem
1.4	14/09/2022	Submitted to the commission	Sabeur Elkosantini, Sonia Gabouj, Rami B.H. Kacem

Executive Summary

The purpose of D1.2 is to present the identified gap between targeted MPQ4.0 skills, existing curricula being offered in both Tunisian and Moroccan partner universities programs and local industrial needs. As a CBHE project, the ENHANCE vision is organised around five main pillars:

- The European vision about Maintenance, Production, and Quality engineering in the context of industry 4.0 (MPQ4.0). The programme country members synthesise the most impacting related work in MPQ 4.0, share the best practices of the teaching programmes in their institutions and finally, their Digital Innovation Hubs (DIHs) services and experimented solutions.
- The partner countries vision about the existing teaching programmes in the involved Tunisian and Moroccan universities. This vision is completed with current practices and new MPQ 4.0 requirements collected from selected industrial partners in different application domains.
- The MPQ 4.0 Learning Framework to cover the gaps and draw the path for training the trainers in the three main topics.
- The MPQ 4.0 pilots' development to create effective skills, competencies and technology acquisition channels to support digital transformation in the industry. The generated materials are to be structured in the Longlife eLearning (LeL) platform to be deployed at each partner countryside.
- The establishment of 2 DIHs, one in Tunisia and one in Morocco to sustain the ENHANCE outcomes and organise their exploitation model to support MPQ 4.0 industrial challenges in both countries.

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1. ENHANCE project Overview

ENHANCE – strENgtHening skills and training expertise for TunisiAN and MorocCan transition to industry 4.0 Era – is an Erasmus Plus project founded under the KA2 Cooperation for innovation and the exchange of good practices (Capacity Building in the field of Higher Education) programme by the European Commission under Grant Agreement N° 619130, to be conducted in the period January 2021 until January 2024. It engages 7 partners from 5 countries with a total budget of 779k€. Its organisation is illustrated in the Figure 1. Further information can be found at http://eplus-enhance.eu/.

The emergence of industry 4.0 concepts and applications brings new paradigms impacting all the industrial business domains when they need to conduct successful digital transformations or increase workshops connectivity. The evolution of Maintenance, Production and Quality Engineering (MPQ 4.0) represents the main application domains where Industry 4.0 produces effective beneficial results.

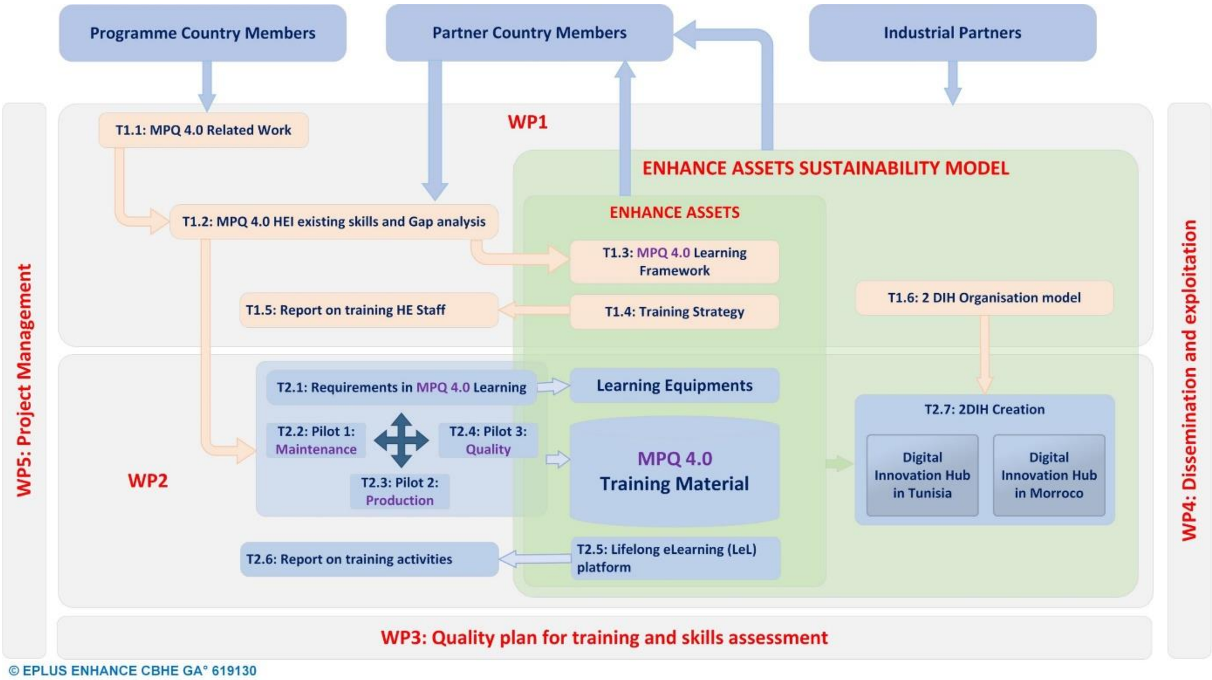


Figure 1 - ENHANCE Project Organisation

The ENHANCE project focuses on building new MPQ training capacities at Higher Education Institutions (HEI) in Tunisia and Morocco to establish interactions between the following stakeholders:

- European universities and research institutions (from France, Germany and Portugal) confirmed MPQ 4.0 competencies, training materials, collaborative research projects, full operational Digital Innovation Hubs (DIH), technology transfer experiences, etc.
- Partner country universities (from Tunisia and Morocco) with teaching and training activities in MPQ and existing connections with their local industrial partners.

The ENHANCE project will create several outputs and two primary tangible outcomes:

- New MPQ 4.0 equipment and training materials developed in connection with the existing training programmes and consolidated through three industrial pilots. The new material will be used to train the trainers and the students in the different partner country universities.
- Two DIHs, one in Tunisia and one in Morocco to sustain the project outcomes through their reuse for training in industry.

ENHANCE aims to become the reference model for creating effective and sustainable training material for MPQ 4.0 in both partner countries with content approved by academia and industry.

2. Introduction

In recent years, the industry in North Africa (also called Maghreb) region, especially Tunisia and Morocco, is facing a historical turning point when considered on a global scale. The digital age comprises a new way of thinking regarding manufacturing and operations. To improve the attractiveness for investment and to meet market requirements of competitivity, in terms of performance, quality, and sustainability, both Tunisia and Morocco need to support industrialization. In this context, this project focus on industry 4.0 and particularly on the three following topics: Maintenance 4.0, Production 4.0 and Quality 4.0, which represent key industrial business processes that particularly need attention, investment and improvement. Through this project, several Tunisian and Moroccan universities and companies showed their interest to develop skills and knowledge to take full advantage of industry 4.0 paradigm and technologies related with these three core business processes of Industry 4.0.

2.1. Purpose of the document

This document is developed as part of the ENHANCE project to conduct a survey on all collaborators, industrial and Tunisian and Moroccan HE ENHANCE partners, based on surveys, in order to determine the gap between acquired skills in HEIs and the identified ones required by industry 4.0 (particularly those related to MPQ4.0). This document will help to consolidate a common understanding of all stakeholders' requirements and the available solutions and training opportunities.

2.2. Reference documents

D1.1 - Literature review about required skills related to MPQ4.0

2.3. Applicability

The document presents the adopted gap analysis working plan for the Assessment of the readiness and needs of Tunisian and Moroccan industry with regards to industry 4.0 requirement in general and with MPQ4.0 (Maintenance4.0, Production4.0 and Quality4.0) skills/technologies particularly. It will also present the result of the analysis of existing curricula in Tunisia and Morocco having courses related to MPQ 4.0. The document will also discuss the gap between targeted MPQ4.0 skills and existing curricula in Tunisia and Morocco having courses related to MPQ 4.0.

2.4. Definitions

In the following, the main concepts used in this document are briefly explained:

- *Skill* – encompasses the knowledge, competencies, and learned ability to perform an activity or job well with determined results
- *Technologies*: set of devices, equipment and infrastructure used for practical purposes.
- *Industry 4.0* – is the ongoing automation of traditional manufacturing and industrial practices, using data exchange and modern smart technologies (e.g., IoT, cloud computing, cyber-physical systems, and cognitive computing) to improve companies' operation, products, and services

- *Maintenance engineering* – is the discipline and profession of applying techniques and engineering skills (e.g., checking, repairing and servicing machinery, equipment, systems and infrastructures) for the optimization of equipment, processes, and procedures
- *Production engineering* – is the discipline of using machines, tools, materials, and human resources and also creating safe and efficient processes for transforming raw materials into high quality products
- *Quality engineering* – is a discipline of engineering concerned with the assurance of the overall quality of the manufactured products and delivered service
- *Higher Education Institutions* – includes organizations (e.g., universities, vocational and technical colleges, community colleges, and other collegiate-level institutions) that offer higher education and award academic degrees or professional certificates
- *Stakeholder* – is any party, individual, or group that has an interest in the project and can either affect or be affected by the project at any stage

2.5. Structure of the document

- Chapter 1 - ENHANCE project Overview
- Chapter 2 - Introduction
- Chapter 3 - Gap Analysis working plan
- Chapter 4 - MQP4.0 targeted skills
- Chapter 5 - Assessment and needs of the PC industry MPQ 4.0 readiness
- Chapter 6 - Curricula and Gap analysis in PC
- Chapter 7 - Cross analysis and recommendations

2.6. List of acronyms

- BIBA: Bremer Institut für Produktion und Logistik GmbH
- CMMS – Computerized Maintenance Management System
- DIH – Digital Innovation Hub
- ECC: Ecole Centrale Casablanca
- HE: Higher Education
- ICT – Information Communication Technologies
- IISE – Institute of Industrial and Systems Engineers
- IIT : International Institute of Technology
- ISEBoK – Industrial and Systems Engineering Body of Knowledge
- ISI – Industrial and Systems Engineering
- MPQ – Maintenance Production Quality
- PC : Partner country
- UCAR: University of Carthage
- UIT : University Ibn Tofail
- ULL: University Lumière Lyon2
- UNL: University Nova Lisbon

3. Gap Analysis working plan

The suggested gap analysis working plan is presented in Figure 2 and Figure 3. The plan includes three steps:

- Step 1: Assessing the readiness and needs of Tunisian and Moroccan industry with regards to industry 4.0 requirements in general and with MPQ4.0 (Maintenance4.0, Production4.0 and Quality4.0) skills/technologies particularly (see section 3.2).
- Step 2: Analyse existing curricula in Tunisia and Morocco having courses related to MPQ 4.0 (see section 3.2). In this project, only curricula including courses related to one of the three targeted topics (Maintenance, Production, and Quality) are analysed. Moreover, only curricula established in Tunisian and Moroccan partner's Universities (UCAR, IIT, ECC and UIT) are analysed.
- Step 3: Analyse the gap between targeted MPQ4.0 skills and existing curricula in Tunisia and Morocco having courses related to MPQ 4.0 (see section3.2.2)

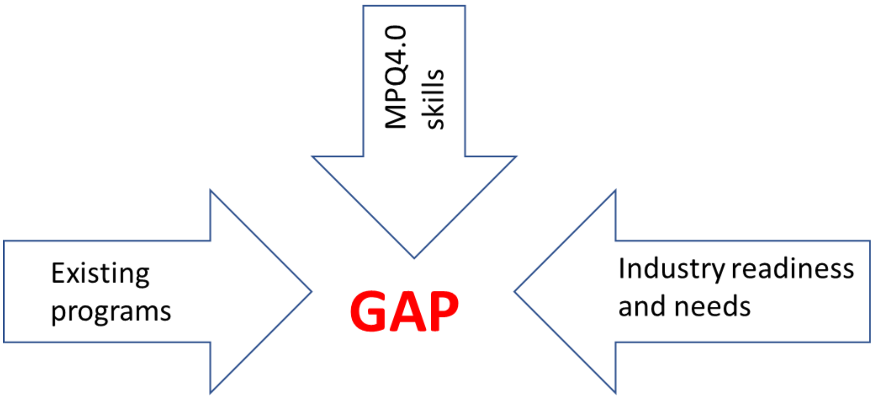


Figure 2: Gap analysis model

These three steps are conducted after identifying skills and technologies required for the three targeted industry 4.0 pillars which are Maintenance, Production and Quality, referred to as MPQ4.0. This task is achieved in Task 1.1 titled "Identify required MPQ4.0 technologies and techniques" and MPQ4.0 skills are identified and discussed in D.1.1 titled "Literature review about required skills related to MPQ4.0". These skills are summed-up in section 4.

Figure 3 illustrates the details of the adopted gap analysis work plan and which are detailed in the following sections.

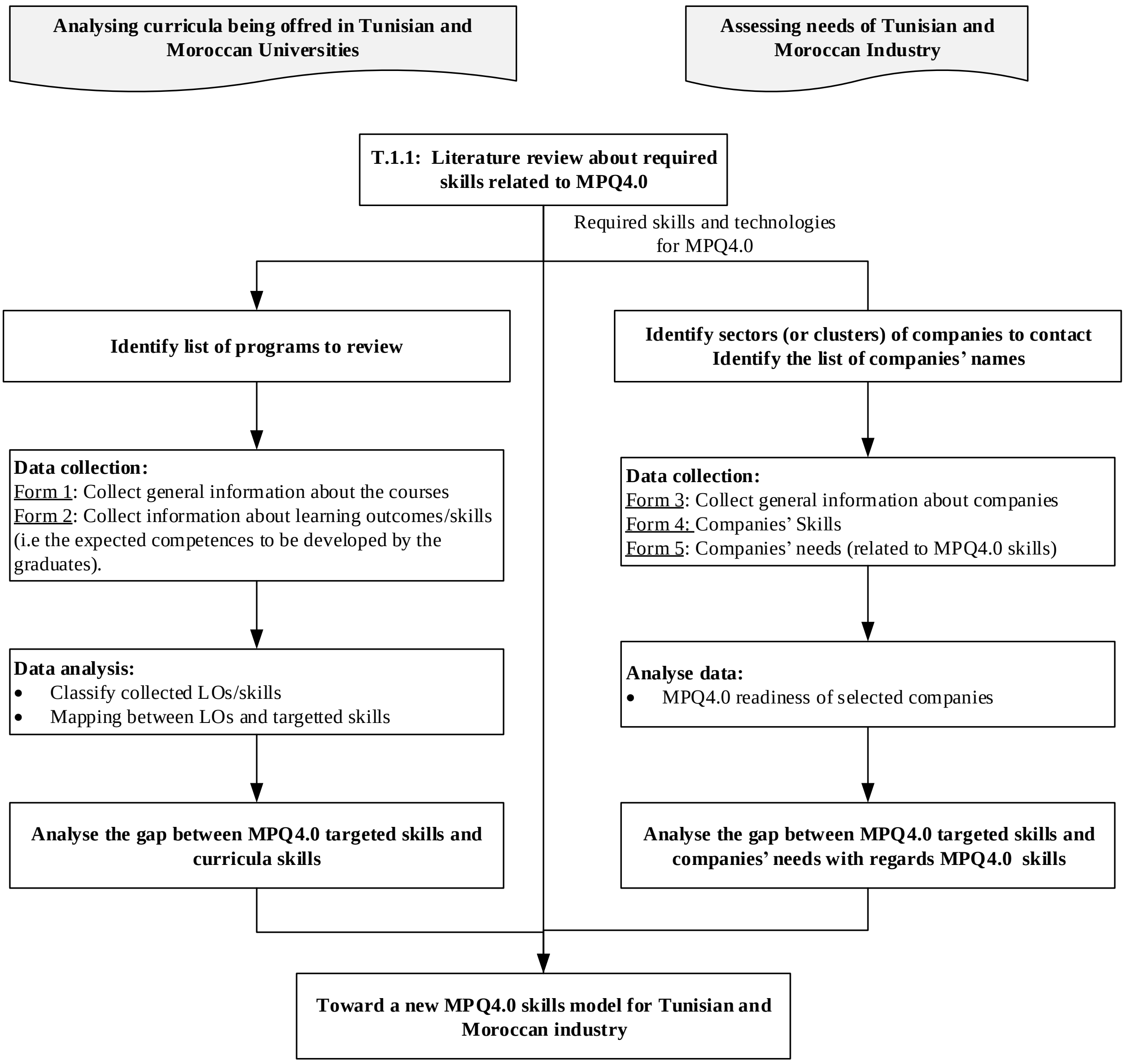


Figure 3: The adopted gap analysis work plan

3.1. Assessing needs of industry

3.1.1. Data collection

This first step in the gap analysis is to conduct a comprehensive analysis of industrial needs. Each PC partner will conduct the analysis with companies assigned in their countries with the support of EU partners. Therefore, ECC will be in charge of companies established in the region of Casablanca (Morocco), UIT will be in charge of companies established in the region of Kenitra and Rabat (Morocco). In Tunisia, UCAR will be in charge of companies established in the region of Tunis and Nabeul while IIT will be in charge of companies established in the region of Sfax.

To collect data, an online industrial workshop was organized on July 7th, 2021. Invitations were sent to both Tunisian and Moroccan SMEs. Moreover, the targeted sectors (or clusters) are as follow:

- Automotive
- Energy
- Financial Service

- Healthcare & Pharma
- Industrial Products
- Private Equity
- Public Sector
- Retail & Consumer
- Technology, Media & Telecoms
- Transportation & Logistics
- Aeronautic
- Food industry

During the workshop, a survey is presented to participants to collected data. The survey, presented in appendix 1 (see section 9), is composed of 20 questions, organized into 5 categories:

- General information including then name of the company, the type of the industry, the region, the number of employees.
- The challenges of digitization and the training of employees in MPQ4.0: 2 questions
    - MPQ.Q1: For your organization, cite 3 most important challenges or obstacles of undertaken digitization initiatives related to MPQ4.0?
    - MPQ.Q2: How your employees are trained in new industry 4.0 technologies and practices
- Maintenance 4.0 readiness: 6 questions
    - MQ1: From the following maintenance practices, what are the deployed ones in your organization?
    - MQ2: Have you carried out a new strategy for transforming the maintenance management model in your organization?
    - MQ3: Are you planning to conduct new digitalization projects of one of the following maintenance processes?
    - MQ4: From the following list, which are the already deployed technologies in maintenance processed in your organization?
    - MQ5: What is the status of the digitalization projects (if they exist) of maintenance processes in your organization?
    - MQ6: In your organization, what are the skills that must be improved for the digital transformation of maintenance processes?
- Production 4.0 readiness: 6 questions
    - PQ1: How production processes are they defined?
    - PQ2: For the production in your organization, what are the processes that were digitalized?
    - PQ3: From the following list, which are the already deployed technologies in production processed in your organization?
    - PQ4: Are you planning to conduct new digitalization projects of one of the following production processes?
    - PQ5: What is the status of the digitalization projects (if they exist) of Production processes in your organization?
    - PQ6: In your organization, what are the skills that must be improved for the digital transformation of production processes?
- Quality 4.0 readiness: 6 questions
    - QQ1: In your organization, which of the following quality practices are currently being deployed?
    - QQ2: For the quality in your organization, what are the processes that were digitalized?

- QQ3: From the following list, which are the already deployed technologies in quality engineering processed in your organization?
- QQ4: What would be the scope of a future quality 4.0 project?
- QQ5: In your organization, what are the skills that must be improved for the digital transformation of production processes?
- QQ6: What is the status of the digitalization projects (if they exist) of quality processes in your organization?

The complete list of questions and their answers (in French) of the survey are provided in appendix 1 (see section 9).

3.1.2. Data Analysis and gap identification

Based on collected answers from the surveys, the gap analysis will focus on :

- Identifying exiting MPQ4.0 projects in Tunisian and Moroccan SMEs and their future projects.
- Identify challenges and difficulties to hire new collaborators having skills related MPQ4.0

3.2. Analysing curricula being offered

The second step of the suggested working plan is to analyse existing curricula being in ENHANCE PC universities (i.e., in UCAR, IIT, ECC and UIT) to identify the gap. Eight programs (five from Tunisia and three from Morocco) are considered in ENHANCE. These programs are of two types: Engineering degree (or bachelor program, an undergraduate program), and Master program (postgraduate program). These programs are mainly from industrial engineering, computer science and computer engineering curricula, which contain courses addressing skills related to MPQ4.0.

Due to confidentiality restrictions, the name of the programs and their affiliation will not be provided in this public version of the deliverable. The following notations will be used instead:

- E1-E5: for engineering curricula (from UCAR, IIT, ECC and UIT)
- M1-M3: Master curricula (from UCAR and UIT)

Figure 4 illustrate the list of considered programs within this task.

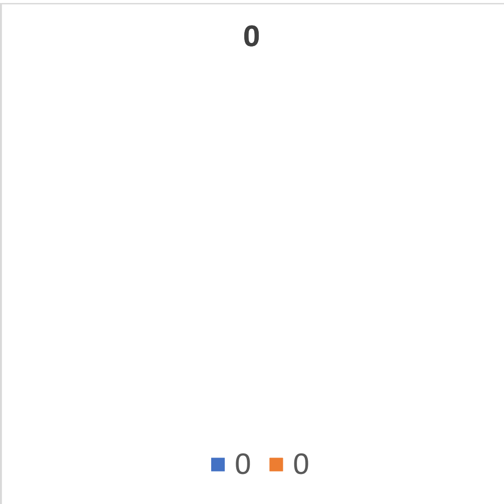


Figure 4: The number of programs

3.2.1. Data collection

Reviewing curricula is based on data collected from partners, using a spreadsheet file sent to the different PC universities (Figure 5 and Figure 6). Two types of information are collected:

- List of courses, hours of contact, credits, number of enrolled students, IEM areas of knowledge and addressed MPQ topics (maintenance, production, quality or all of them) (see Figure 5)
- Addressed MPQ-competences, skills and covered technologies

Figure 5 illustrates the spreadsheet that is sent to different curricula leaders.

Name of the program :								
Type of the program :								
Institution/Faculty:								
University:								
Number of students								
					Hours			
Name of the course	Semester	Main scientific area*	MPQ	Credit	Lecture (C)	Tutorial (TD)	Lab (TP)	Project

Figure 5 – General information sheet

In this project, we adopted the list of scientific areas identified in the Industrial and Systems Engineering Body of Knowledge (ISEBoK) prepared by Institute of Industrial and Systems Engineers (IISE) [Industrial and Systems Engineering Body of Knowledge, 2021]. IISE is an international, nonprofit association that provides leadership for the application, education, training, research, and development of industrial engineering and that was founded in 1948. ISEBoK is composed of fourteen knowledge areas. Each knowledge area is represented by an outline that defines what needs to be known to achieve a mastery in the field of Industrial and Systems Engineering (ISE). A list of references is included in each knowledge area providing the reader with a resource to the requisite detail necessary to obtain a mastery of the areas provided in the ISEBoK.

The main scientific areas are the following:

- Work Design and Measurement: covers the tools and techniques used to establish the time for an average worker to carry out a specified task at a defined level of performance in a defined work setting. The analysis associated with Work Design and Measurement focuses to create a standardized work environment that maximizes worker satisfaction and creates the best possible value for the enterprise and its customers.
- Operations Research and Analysis: includes a variety of problem-solving techniques focused toward improved efficiency of systems and support in the decision-making process. The realm of Operations Research involves the construction of mathematical models that aim to describe and/or improve real or theoretical systems and solution methodologies to gain real-time efficiency.
- Engineering Economic Analysis : is a specific knowledge area of economics focused on engineering projects. Industrial Engineers need to understand economic viability of any potential problem solution
- Facilities Engineering and Energy Management: Facilities Engineering is concerned with the arrangement of physical resources to support the optimal production and distribution of goods and services. Energy Management includes the planning and operation of energy

required in facilities to support the production and distribution of goods and services. Their close interrelationship accounts for their knowledge topic described in a common section.

- Quality & Reliability Engineering: covers the tools and techniques employed that help to prevent mistakes or defects in manufactured products or service processes that avoids problems when delivering solutions or services to customers. A closely related knowledge area is Reliability Engineering. These concepts are used to determine the ability of a system or component to function under stated conditions for a specified period of time
- Ergonomics and Human Factors: concerned with the design and analysis of equipment and devices that fit the human body and its cognitive abilities. The knowledge area includes contributions from anthropometry, statistics, psychology, physiology, biomechanics, industrial design, graphic design, operations research, and other disciplines. It is the study of designing equipment and devices that fit the human body and its cognitive abilities. The areas of emphasis are: Physical Ergonomics, Cognitive Ergonomics, and Organizational Ergonomics.
- Operations Engineering & Management: is an area of technical management dealing with the design and analysis of production and service processes. From an Industrial Engineering viewpoint this knowledge area employs tools and techniques to ensure business operations function efficiently, using as few resources as needed, and effectively in meeting customer requirements.
- Supply Chain Management: covers the movement, production, and storage of raw materials, work-in-process inventory, finished goods, and services from the point of origin to the point of consumption or use. Suppliers, manufacturers, intermediaries, stores, and service enterprises are involved in the delivery of products and services to end customers in a supply chain.
- Engineering Management: is a focused area of management dealing with the application of engineering principles to business practice. Whereas Operations Engineering and Management focuses on the design and analysis of production and service processes, Engineering Management deals with the technical business side of the organization
- Safety: addresses the origins or workplace accidents, regulations and management practices towards mitigating hazard exposures, preventing harm and reducing liability. Safety engineering also addresses methods and measures for recognizing and controlling workplace physical hazards, as well as approaches for dealing with accidents and facilitating recovery
- Information Engineering: is an approach to planning, generating, distributing, analyzing and using the collection of data in systems to facilitate decision making and business communication
- Design and Manufacturing Engineering: focuses on tools and techniques to conceptualize, engineer, produce, and qualify physical products across feature scales, production quantities, and application domains. From an industrial engineering viewpoint, this knowledge area is concerned with the development, optimization, and standardization of methods to transform raw materials into functional products to satisfy the applications' and stakeholders' requirements in the most time and cost efficient manner.
- Product Design and Development: is the efficient and effective generation and development of ideas through a process that leads to new products. From an industrial engineering knowledge view, it is the processes and analysis employed to support efficient decision-making during Product Design and Development

- Systems Design and Engineering: deals with integrating aspects of other engineering disciplines, enofing that all likely aspects of a project or system are considered and efficiently integrated together. This area contains a strong cross-coupling to Industrial Engineering.

The aim of the second excel sheet (see Figure 6) is to collect information about addressed MPQ-competences, skills, and covered technologies. As it will be discussed in section 4, the following competencies and skills are considered:

- Competence 1: Capability to achieve integrated Systems and Architectures
  - Skill 1.1: Ability to achieve digitalization of modeling & design
  - Skill 1.2: Ability to achieve integration and interoperability
  - Skill 1.3: Ability to achieve digital transformation, implementation, migration, deployment
- Competence 2: Capability to enable collaborative, cooperative, Self/Emerging systems
  - Skill 2.1: Ability to achieve innovative human-to-human interactions
  - Skill 2.2: Ability to achieve innovative human-to-computer/machine interactions
  - Skill 2.3: Ability to achieve innovative machine-to-machine interactions
- Competence 3: Capability to enable advanced & smart connectivity & connectedness
  - Skill 3.1: Ability to acquire big DIK (source, type, size, frequency, quality)
  - Skill 3.2: Ability to transmit DIK
  - Skill 3.3: Ability to connect mobile, autonomous resources (mobile robotics, drones, unmanned vehicles)
- Competence 4: Capability to embrace core manufacturing process automation & sustainability
  - Skill 4.1: Ability to link enterprise strategy to manufacturing capabilities
  - Skill 4.2: Ability to achieve additive manufacturing
  - Skill 4.3: Ability to achieve process automation & control
  - Skill 4.4: Ability to achieve energy efficiency & sustainability
- Competence 5: Capability to achieve DIK Lifecycle Management
  - Skill 5.1: Ability to manage DIK and related infrastructure
  - Skill 5.2: Big DIK collection and storage
  - Skill 5.3: Data processing & analysis
  - Skill 5.4: Data governance & security
- Competence 6: Capability to achieve prescriptive & adaptive Decision Support
  - Skill 6.1: Ability to analyze and understand the past
  - Skill 6.2: Ability to predict and anticipate
  - Skill 6.3: Ability to make prescriptive and adaptive decisions
  - Skill 6.4: Ability to evaluate residual risks, operational excellence and performance
  - Skill 6.5: Ability to satisfy standards

Finally, we have considered nine different technologies, which are adopted in the deliverable D1.1, titled "Literature review about required skills related to MPQ4.0". According to Boston Consulting Group, there are nine technologies that form the building blocks of Industry 4.0, the future of industry (Rüßmann et al., 2015):

- Big Data and analytics - Allows to optimize production quality, save energy and improve equipment efficiency. In I4.0, the collection and exhaustive evaluation of data from many different sources (equipment and production systems, customer management systems ...)

becomes a standard to support real-time decision making. The concept acts as a large database and appears in the industrial world due to the increase in the amount of data to be analyzed from different sources, such as equipment and systems.

- Autonomous Robot - The concept provides greater utility for automation, making it flexible and collaborative in that it interacts with other robots and works hand in hand with humans, safely, learning from them.
- Simulation - In the engineering phase, 3-D simulations of products, materials and production processes are already used, but in the future, simulations will be used more intensively in industrial operations. These simulations will leverage real-time data to mirror the physical world into a virtual model, which may include machines, products, and humans.
- The Industrial Internet of Things - With the industrial internet of things, more devices and equipment will be integrated and connected through technological standards. This will allow the devices to communicate and interact with each other.
- Cybersecurity - The general industry still depends on unmanaged or closed production and management systems. However, with increased connectivity and use of standard communication protocols involved in Industry 4.0, the need to protect critical systems and industrial production lines from cyber threats will increase dramatically.
- The cloud - Some cloud-based software and analytics applications are already being used, but with Industry 4.0, a greater number of production-related tasks requires more data exchange between sites and enterprises. At the same time, the performance of cloud technologies will improve, reaching reaction times of a few milliseconds. As a result, the data and functionality of the machines will increasingly use of cloud computing, allowing more data-driven production systems services.
- Additive Manufacturing - Currently 3D printing is mainly used for prototyping and production of individual components. With Industry 4.0, this technology will be widely used to produce small batches of custom products. We will have decentralized, high performance additive production systems, reducing transport and storage distances.
- Augmented Reality - Augmented Reality systems are based on supporting a variety of services, such as parts selection in a warehouse and maintenance operations through mobile devices. This technology at the service of production management is still at an early stage, but in the future companies will give augmented reality greater importance, to provide workers with real-time information to improve decision-making.
- AI/ML/DL – Artificial intelligence has become the most disruptive technology called to revolutionize the management and business models of organizations. AI is one of the main technological advances that is allowing Industrials to digitalize their different processes. Machine Learning (ML) and Deep Learning (DL) are forms of AI

In the second excel sheet, faculty members must select the level of coverage of each technology for each skill. The considered level of coverage is :

- 0 - Not Covered : The skill/Technology is not addressed
- 1 - Less Covered : The skill/Technology is addressed below requirements
- 2 - Acceptable : The skill/Technology is addressed such as to meet minimally the requirements
- 3 - Ensured : The skill/Technology is addressed such as to clearly meet the requirements
- 4 - Highly Covered : The skill/Technology is addressed beyond requirements

NB:
- In this sheet, professors are kindly asked to choose an answer from the combo-box in each cell. The objective is to understand what technolgies are covered in the course for each skills (if they are addressed of course)
- If the skill is not addressed, do not check any technologies

NB: Level covered :
- 0 - Not Covered : The skill/Technology is not addressed
- 1 - Less Covered : The skill/Technology is addressed below requirements
- 2 - Acceptable : The skill/Technology is addressed such as to meet minimally the requirements
- 3 - Ensured : The skill/Technology is addressed such as to meet clearly the requirements
- 4 - Highly Covered : The skill/Technology is addressed beyond requirements

		Technologies								
		IoT	BigData and analytics	Simulation /Emulation	Cloud computing	AI/ML/DL	Augmented reality	Autonomous robots	Additive Manufacturing	Cyber security
Completence	Skills	Level covered	Level covered	Level covered	Level covered	Level covered	Level covered	Level covered	Level covered	Level covered
Competence 1	Skill 1.1: Ability to achieve digitalization of modeling & design									
	Skill 1.2: Ability to achieve integration and interoperability									
	Skill 1.3: Ability to achieve digital transformation, implementation, migration, deployment									
Competence 2	Skill 2.1: Ability to achieve innovative human-to-human interactions									
	Skill 2.2: Ability to achieve innovative human-to-computer/machine interactions									
	Skill 2.3: Ability to achieve innovative machine-to-machine interactions									
Competence 3	Skill 3.1: Ability to acquire big DIK (source, type, size, frequency, quality)									
	Skill 3.2: Ability to transmit DIK									
	Skill 3.3: Ability to connect mobile, autonomous resources (mobile robotics, drones, unmanned vehicles)									
Competence 4	Skill 4.1: Ability to link enterprise strategy to manufacturing capabilities									
	Skill 4.2: Ability to achieve additive manufacturing									
	Skill 4.3: Ability to achieve process automation & control									
	Skill 4.4: Ability to achieve energy efficiency & sustainability									
Competence 5	Skill 5.1: Ability to manage DIK and related infrastructure									
	Skill 5.2: Big DIK collection and storage									
	Skill 5.3: Data processing & analysis									
	Skill 5.4: Data governance & security									
Competence 6	Skill 6.1: Ability to analyze and understand the past									
	Skill 6.2: Ability to predict and anticipate									
	Skill 6.3: Ability to make prescriptive and adaptive decisions									
	Skill 6.4: Ability to evaluate residual risks, operational excellence and performance									
	Skill 6.5: Ability to satisfy standards									

Figure 6 – Skills/Technologies sheet

3.2.2. Analysing the gap

The objective is to identify gaps and world trends and developments in Industrial Engineering and particularly those related to MPQ4.0 skills and technologies. The adopted methodology for the gap analysis based on a bottom-up analysis, i.e., from courses to overall program analysis:

- For each course:
  - ✓ How technologies are covered for each competence
  - ✓ How competencies are addressed
- For each topic (M/P/Q):
  - ✓ How technologies are covered for each competence
  - ✓ How competencies are addressed
- For each program:
  - ✓ How technologies are covered for each competence
  - ✓ How competencies are addressed

To calculate the level coverage of technologies and skills for each course and program, the maximum operator is used. For the level of coverage of competence for a given program, the mean of level of covered skills of the associated competence. For example, the level of coverage of the competence 1 is the mean of the level of the skill 1.1, 1.2 and 1.3.

Finally, radar charts were used to visualize the level of coverage for each competence and skill for each program. After the analysis of collected data, each PC university must identify the targeted level for each technology and skills to identify gaps and improvements that should be undertaken within this project.

4. MQP4.0 targeted skills

In deliverable D1.1, titled “Literature review about required skills related to MPQ4.0”, we suggested an abstraction framework based on competencies, skills, and abilities. Therefore, a reduced set of 6 interrelated competencies were developed. Each competence involves a set of skills that collectively achieve the competence. Each skill involves a set of (know-how) abilities that regularly appear through the description of industry 4.0 projects and technology implementations. Interrelation of competencies means that each competence provides support for, and complementarity to, other competencies.

4.1. Competence 1: Capability to achieve integrated systems and architectures

Industry 4.0 introduces a set of technologies, practices and paradigms that do not work standalone, but rather work collectively in synergy to achieve higher benefits, in terms of added value, quality of service and performance. Achieving MPQ4.0 success requires a new mindset, as well as new methodologies, tools and practices to design, develop, and operate such systems in a more integrated, interoperable and coordinated way. Competence 1 brings an answer to this requirement. It focuses on abstraction capabilities and model-based engineering to design, develop, and operate MPQ4.0 processes in such a way to guarantee their synergistic operation within integrated architectures.

Therefore, the following skills are considered in this competence:

- Skill 1.1: Ability to achieve digitalization of modeling & design

- Skill 1.2: Ability to achieve integration and interoperability
- Skill 1.3: Ability to achieve digital transformation, implementation, migration, deployment

4.2. Competence 2: Capability to enable collaborative, cooperative and self-emerging systems

Industry 4.0 work environments are characterized by smart production objects and resources able to communicate, and process data, information, and knowledge in an autonomous and distributed way. Those smart production objects and resources are no longer inert/passive, but rather become active and can participate in the different data and decision-making processes involved in the MPQ4.0 engineering fields. This activeness creates new ways to interact between humans, computers/machines, products, and services. Therefore, there is a need to address these new interaction opportunities and possibilities in a systemic and comprehensive way. Competence 2 brings an answer to this requirement. It focuses on the skills necessary to achieve innovative interactions, between humans, between humans and computers/machines, and among computers/machines.

Therefore, the following skills are considered in this competence:

- Skill 2.1: Ability to achieve innovative human-to-human interactions
- Skill 2.2: Ability to achieve innovative human-to-computer/machine interactions
- Skill 2.3: Ability to achieve innovative machine-to-machine interactions

4.3. Competence 3: Capability to enable advanced and smart connectivity and connectedness

Industry 4.0 work environments require production objects, resources (including augmented operators/collaborators, machines, robots, logistics, storage and material/products), and facilities to be interconnected, to access, share and exchange data, information, and knowledge in a distributed/decentralized way, and in real-time to create value, to participate actively in decision processes, and to enable advanced data analytics, business intelligence and decision making. Connectivity and connectedness are therefore essential requirements and represent the backbone technologies of industry 4.0. Competence 3 brings an answer to this requirement. It focuses on the skills necessary to deal with the implementation, deployment and operation of the networking and computing infrastructure required through the management lifecycle of data, information, and knowledge. This networking and computing infrastructure spans the acquisition, transmission of data, information, and knowledge, as well as interconnection and operation of networking and computing systems, in a way to achieve systems of networked computing systems.

Therefore, the following skills are considered in this competence:

- Skill 3.1: Ability to acquire big DIK (source, type, size, frequency, quality)
- Skill 3.2: Ability to transmit DIK
- Skill 3.3: Ability to connect mobile, autonomous resources (mobile robotics, drones, unmanned vehicles)

4.4. Competence 4: Capability to embrace core manufacturing process automation and sustainability

Whereas competence 1 focuses on designing and modelling transformation strategies and plans, it is necessary to be able to link those strategies to core manufacturing capabilities and technologies, and to deploy those strategies in manufacturing environments. Also, it is necessary to be up to date with the latest smart factory technologies, including processing and automation technologies. Moreover, it is necessary to operate the smart factory of the future in a sustainable and energy efficient way. Therefore, competence 4 brings an answer to these requirements. It focuses on the skills required to map enterprise strategies, architectures and transformation projects to core manufacturing capabilities, to be able to select the suitable technologies for the envisioned strategies. It also focuses on providing learners and trainees with the skills required to deal with the latest advances in core manufacturing, material processing and automation technologies. Strategies, capabilities and technologies are dealt with within a sustainability and energy efficiency framework to ensure lean, green and sustainable growth and value creation.

Therefore, the following skills are considered in this competence:

- Skill 4.1: Ability to link enterprise strategy to manufacturing capabilities
- Skill 4.2: Ability to achieve additive manufacturing
- Skill 4.3: Ability to achieve process automation & control
- Skill 4.4: Ability to achieve energy efficiency & sustainability

4.5. Competence 5: Capability to achieve data, information and knowledge (DIK) lifecycle management

In industry 4.0 work environments, data, information, and knowledge (DIK) represent the flows materializing value creation and enrichment. DIK become big (i.e., multiple sources, sizes, features, time scales, etc.), and go through a lifecycle that has to be managed timely, securely and reliably. Competence 5 brings an answer to these requirements. It focuses on the skills necessary to model complex systems involving big DIK and to manage their related infrastructure. It also focuses on the necessary skills to implement, deploy, and operate big DIK platforms to enable the collection, storage, and processing of big DIK. It covers the necessary skills to preserve the quality of big DIK and brings essential data science and analysis tools. It finally covers big DIK governance and security issues.

Therefore, the following skills are considered in this competence:

- Skill 5.1: Ability to manage DIK and related infrastructure
- Skill 5.2: Big DIK collection and storage
- Skill 5.3: Data processing & analysis
- Skill 5.4: Data governance & security

4.6. Competence 6: Capability to achieve prescriptive and adaptive decision support

In industry 4.0 work environments, decision support mechanisms rely on big DIK to innovate and create new added value. Decision support requires being able to capture current system states, events and dynamics (what is happening), understand and contextualize them considering the history and past states (what happened and why did it happen), and predict future states, events and dynamics (what will happen) in order to make proactive, anticipatory and prescriptive decisions (what to do to make it happen) in such a way to maintain or enhance performance and quality of service. Competence 6 brings an answer to these requirements. It provides skills to analyse big DIK to achieve diagnosis and prognosis. It provides skills to achieve competitive awareness and intelligence, predictive and prescriptive market and manufacturing system analysis.

Therefore, the following skills are considered in this competence:

- Skill 6.1: Ability to analyse and understand the past
- Skill 6.2: Ability to predict and anticipate
- Skill 6.3: Ability to make prescriptive and adaptive decisions
- Skill 6.4: Ability to evaluate residual risks, operational excellence and performance
- Skill 6.5: Ability to satisfy standards

5. Assessment and needs of the PC industry MPQ 4.0 readiness

For the assessment of the needs of the PC industry MPQ 4.0 readiness, the project organized its first online industrial workshop is organized on July 7th, 2021 (link of the workshop : https://eplus-enhance.eu/index.php/1st-enhance-industrial-workshop-2021/). Invitations were sent to both Tunisian and Moroccan SMEs. During the workshop, and even after, a survey with 20 questions was sent to SMEs to collect data. The link of the survey is : https://enquetes.univ-lyon2.fr/index.php/919576.

A total of 32 companies have answered the survey. The number of Tunisian companies is 19 and the number of Moroccan companies is 13. Selected companies are classified according to the sectors already presented in section 3.1 (see Figure 7).

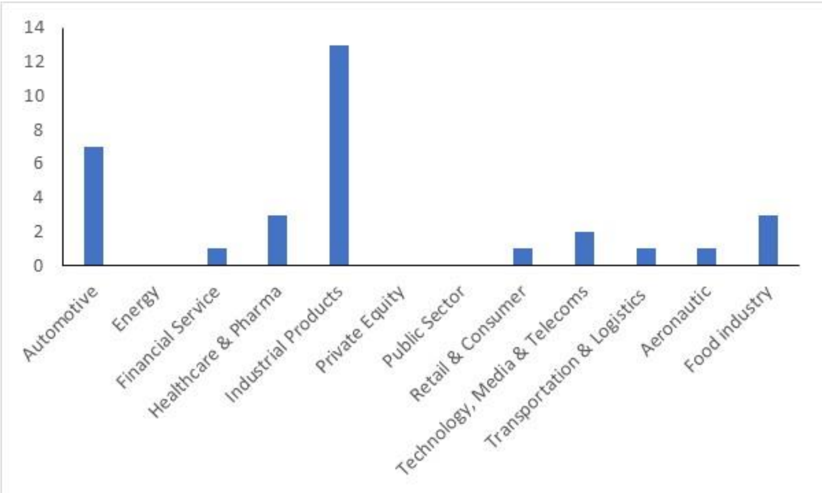


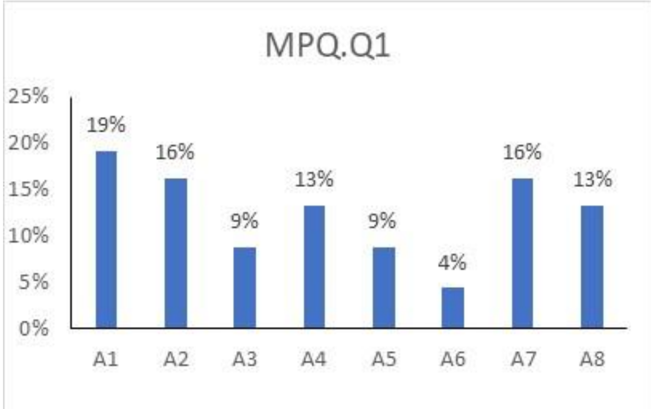
Figure 7 - Number of companies classified by industrial sectors

The following sections will discuss the following issues:

- Challenges of digitization and the training of employees in MPQ4.0
- Needs and readiness of local industry for the three following topics: Maintenance 4.0, Production 4.0 and Quality 4.0. For each topic, the following issues are discussed:
  - The as-is: the actual digitalization projects
  - The to-Be: Interest in I4.0 and future digitalization projects
  - Skills development/training

5.1. Challenges of digitization and the training of employees in MPQ4.0

The analysis of collected answers of the survey received from 32 companies regarding the challenges of digitalization of some MPQ processes (question MPQ.Q1) and difficulties related to collaborators training (question MPQ.Q2) shows that most of the industries face a real difficulty to hire new collaborators/employees with MPQ4.0 skills and who are familiar with industry 4.0 technologies (Challenge 1 -A1- and Challenge 7 - A7 , see Figure 8)

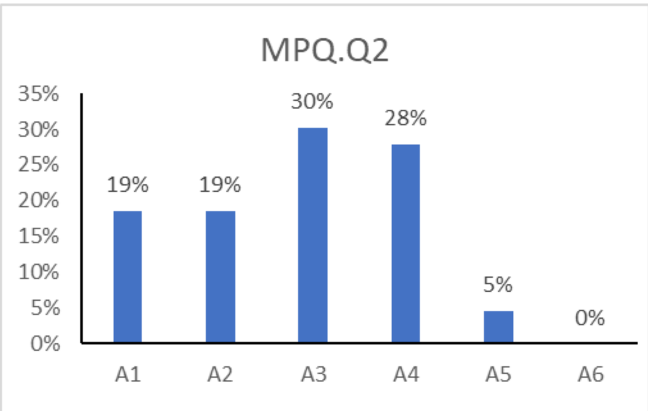


A1: Lack of technologies and infrastructure; A 2: Difficulties in ensuring continuous training of employees; A 3: Ability to rethink MPQ processes after change / digitization; A 4: Resistance to organizational changes; A 5: Reluctance for technical and technological difficulties; A 6: Reluctance regarding data security and confidentiality; A 7: Difficulties (expertise, cost) in recruiting human skills externally; A 8: Lack of financial support

Figure 8 – Digitalization challenges

Moreover, the analysis shows that there is a lack of collaboration between Tunisian and Moroccan Universities and local industry. Most of training is achieved by self-training (using online tools or sharing experience) or through an external training organization (see

Figure 9). To bridge this gap, the project will enhance the capability of PC universities in accompanying PC industries through training workshops, dissemination seminars and implemented pilots. Indeed, one aim of the project is to strengthen the university-industry partnership in Tunisia and Morocco.



A 1: Online training; A 2: External organisation; A 3: self-training; A 4: Sharing experience; A 5: Partnerships/Agreements with universities; A 6: Others

Figure 9 – Training alternatives

5.2. Maintenance 4.0

The analysis of the 2 questions dedicated to assessing the "as-is" for the maintenance 4.0 readiness (questions MQ1 and MQ4, see Figure 10) reveals that the most commonly used technology is the Computerized Maintenance Management System (CMMS) with 30% of companies. Only few companies have deployed recent industry 4.0 technologies such as IoT (with 11%), cloud computing (6%) or mobile solutions (8%). Some technologies such as virtual reality is not yet deployed by any company.

Regarding deployed maintenance inspection techniques, results show that 70% of companies adopted the periodic inspection (37% periodic inspection only and 34% periodic inspection based on human expertise and collected data). Only few companies have deployed real-time maintenance monitoring. Indeed, 21% of companies adopted real-time maintenance techniques using well-defined rules and 8% of companies adopted predictive maintenance.

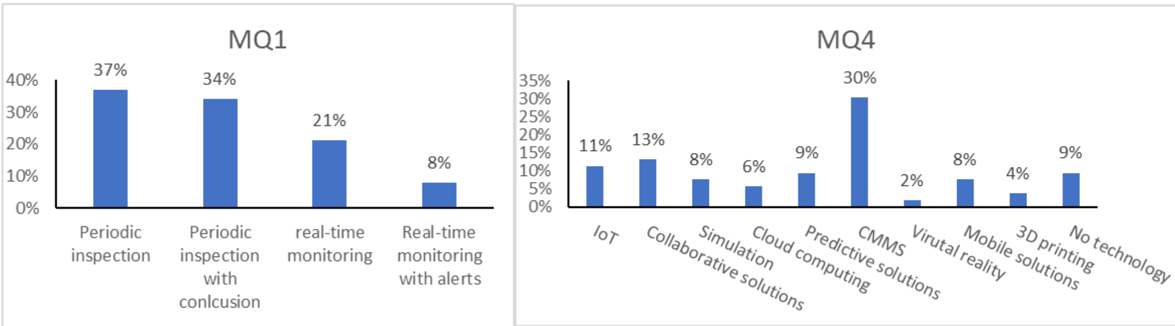
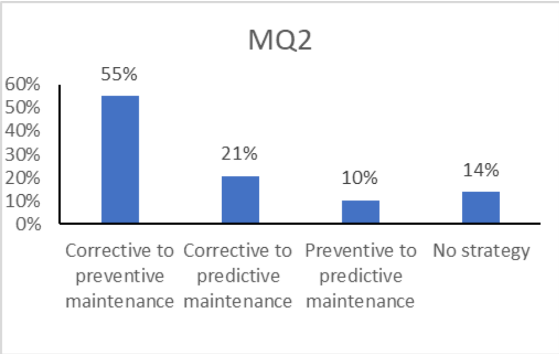


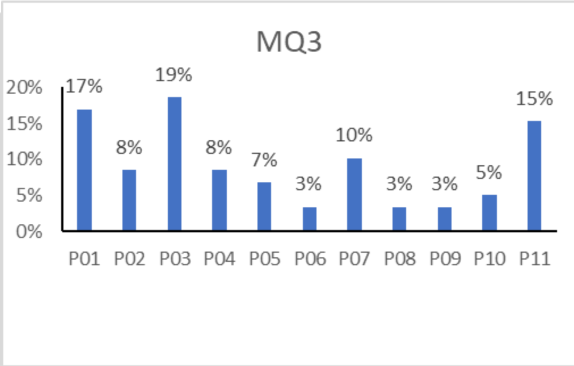
Figure 10 - The "As is" for maintenance 4.0

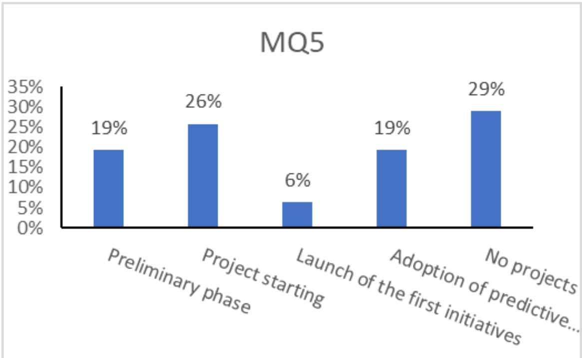
The analysis of answers to question MQ2, concerning the interest of companies to improve their existing maintenance management models, shows that most of them have already started their reflection to develop new strategies to transform their maintenance management model. For example, 55% of companies are working on projects to setup new preventive maintenance techniques and 21% of companies are working on projects to setup new predictive maintenance techniques. Although this interest to new trends in maintenance, most of project are in early stages (19% or transformation projects are still in designs of projects guidelines while 26% are in the starting phase). It is important to note that 29% of companies have not yet started any project of digitalization.

However, as noted in above, few companies have deployed preventive maintenance, only 10% of companies are willing to upgrade their maintenance management model from predictive to preventive.

According to the response of companies, the most important maintenance processes that need to be digitalized are the "P03 - Planification of maintenance operations" (with 19% of answers), "P11 - Performance management of maintenance" (with 11%) and "P01 - training" (with 17% of answers). Therefore, existing curricula should focus on related skills (see Figure 11). Other processes are also highlighted by companies as processes that need to be digitalized. The complete list of processes is provided in the appendix 1 (see section 9).



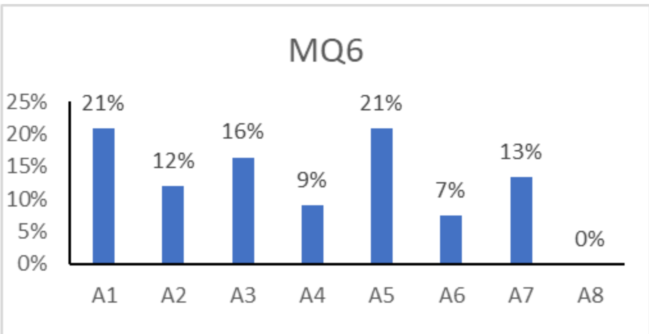




A1: Training and qualification process of maintenance operators; A2: Spare parts and maintenance tools inventory management process; A3: Maintenance planning process; A4: Maintenance intervention process; A5: Data acquisition, inspection and diagnostic process; A6: Maintenance data sharing process, vertical and horizontal integration with other departments and stakeholders; A7: Equipment life and health assessment process; A8: Aging assessment and remaining life estimation (RUL) process; A9: Life extension and extension process; A10: End of life management process (decommissioning, re-conversion, sale); A11: Maintenance performance management process.

Figure 11 – Interest to I4.0 and future digitalisation projects

The analysis of the employee training dimension (see Figure 12) of the survey sustains that both Tunisian and Moroccan industry needs support to train the employee in many technologies such as IoT (A3, with 16%), Horizontal and vertical systems integration (A1, with 21%), preventive and predictive maintenance (A5, with 21%) or Innovation management (A7, with 13%).



A 1: Design, development and implementation of integrated systems and architectures; A 2: Development and management of collaborative, cooperative, autonomous / emerging applications and systems; A 3: Deployment of intelligent connectivity solutions; A 4: Data, Information and Knowledge Management; A 5:Advance and prescriptive decision-making; A 6: Virtualization and cloud services ; A 7: Innovation management; A 8: Others

Figure 12 – Maintenance 4.0 skills development/training

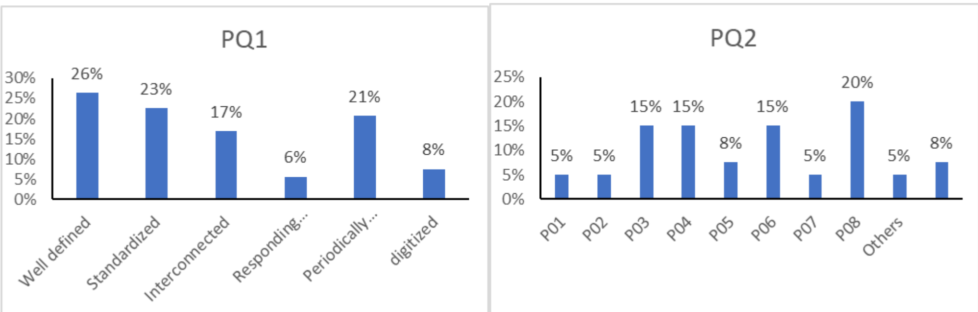
To sum up, the analysis of the Maintenance 4.0 readiness can be summarized as follow:

- Few companies used preventive or predictive maintenance in their organization (only 10%) although their interest in such techniques. Indeed, many companies showed their interest to new maintenance management models, but they need support as they suffer lack of skills
- Most of the companies have highlighted the importance of "planification of maintenance operation" as a key process that should be digitalized
  Most of the companies lack use of recent and MPQ4.0 related technologies such as IoT, cloud computing, VR and IA. The most used technology is the Computerized Maintenance Management System (CMMS).

5.3. Production 4.0

First, we analyse the information provided by the two questions dedicated to assessing the "as-is" for the Production 4.0 readiness (questions PQ1 and PQ2, see Figure 13). Thus, according to Question PQ1, which asks for the kind of applied production process, we deduce that there is no significant common practice for production. Indeed, only a small majority of companies, of around 26%, adopts a "Well defined" production process (P01). Next comes the "Standardized" and "Periodic Analysis" processes, used by 23% and 21% of companies respectively. Nevertheless, only few companies of around 6% have deployed the process of "Responding to changes autonomously/automatically and in real-time", which indicates that some companies have not yet adopted the spirit of industry 4.0 and there is a real potential of development in their production process.

Considering the question PQ2, which provides information about "what processes have been transformed by an industry 4.0 solution?", Figure 13 shows that 20% of the observed companies have transformed the "Monitoring Production Process" (P08) and 15 % have transformed the process "Manufacturing" (P06). Concerning the other process, we deduce that few companies have been interested in involving industry 4.0 solutions. For scheduling process, no company have tried to use industry 4.0 solutions. The complete list of processes is provided in appendix 1 (see section 9).



R1: Design and Development Process; R2: Requirements management process (forecasts and/or sales orders); R3: Inventory Management and Procurement Process; R4: Planning Process; R5: Scheduling Process; R6: Product realization process (Manufacturing); R7: Resource management process (human and material); R8: Production monitoring Process; R9: Other

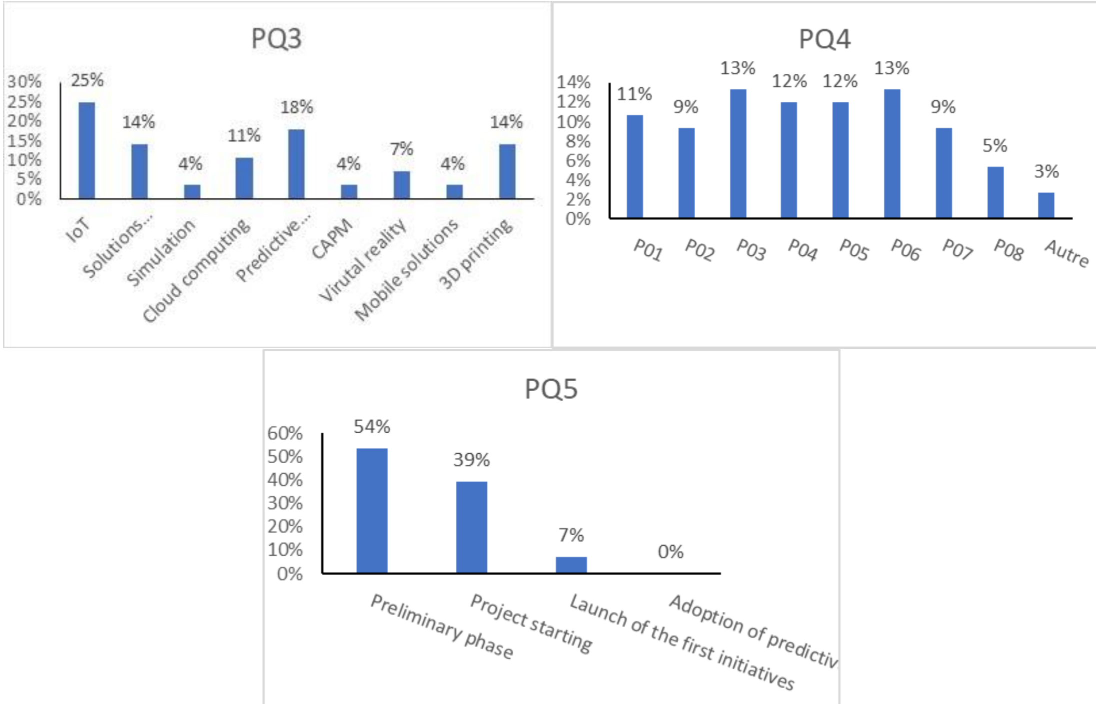
Figure 13 – The As is for Production 4.0

The questions PQ3, PQ4 and PQ5 aim to provide information about the interest of companies in I4.0 and future digitalisation projects (see Figure 14).

On the other hand, the question PQ5 asks for "If companies are planning to launch a new Industry 4.0 project, how far along is your Industry 4.0 project deployment?". The responses of companies are illustrated in Figure 14. The analysis of these responses reveals that until now there is no company that has finished the adoption and the implementation of an Industry 4.0 project. Nevertheless, most companies, about 54%, declared that they are planning to launch a new industry 4.0 project and they are in the phase of study, planning and /or evaluation. All remaining observed companies (40%) declare that they are Launching a pilot project.

On the other hand, the question PQ5 asks for "If companies are planning to launch a new Industry 4.0 project, how far along is your Industry 4.0 project deployment?". The Reponses of companies are showed in Figure 14. The analysis of these responses reveals that until now there is no company that have finished the adoption and the implementation of an Industry 4.0 project. Nevertheless, most companies, about 54%, declared that they are planning to launch a new industry 4.0 project and they are in the phase of study, planning and /or evaluation. All remaining observed companies (40%) declare that they are Launching a pilot project.

With regards to technologies (question PQ3), some industry 4.0 related technologies are used by companies such as IoT (25%), predictive techniques (18%) or 3D printing (14%). Other technologies such as Cloud Computing or Virtual Reality are not well considered by local industry.

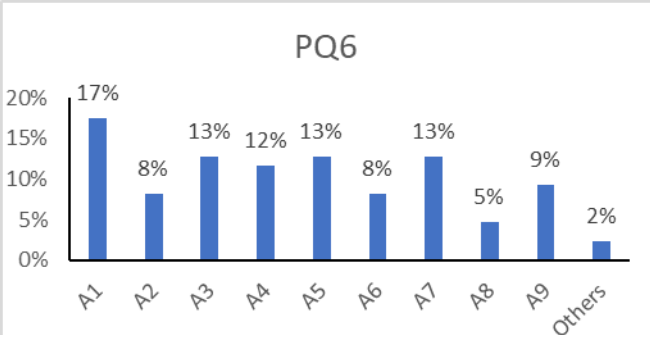


A1: Design and Development Process; A2: Requirements management process (forecasts and/or sales orders); A3: Inventory Management and Procurement Process; A4: Planning Process; A5: Scheduling Process; A6: Product realization process (Manufacturing); A7: Resource management process (human and material); A8: Production monitoring Process; A9: Other

Figure 14 – Interest to I4.0 and future digitalisation projects

Next, we provide in Figure 15 responses to a question asked to know how observed companies react to Skills development and training, regarding the industry 4.0 transformation. Thus, we have asked the following question: What skills in your organization need to be improved for digital manufacturing transformation?

According to the provided information, we deduce that there is no a significant common practices. 14 % of companies indicate the "A1 : Design, development and management of automated production systems"; the "A3: Design, development and implementation of integrated systems and architectures"; "A4: Development and management of collaborative, cooperative, autonomous/emergent applications and systems" and A5: Deployment of agile and intelligent connectivity solutions". Note also that very few companies (A8, 5%) have indicated the Virtualization and cloud services.



A1: Design, development and monitoring of automated production systems (industrial automation robotics; etc.); A2: Innovative design/manufacturing (new processes; intelligent materials/products; ecodesign; etc.); A3: Design, development and implementation of integrated systems and architectures (Horizontal integration; Vertical integration; Integrated intelligence); A4: Development and piloting of collaborative and cooperative applications and systems, autonomous/emergent (Human-Computer Interaction; Machine-Machine Interaction; user-centered design); A5: Deployment of agile and intelligent connectivity solutions (IoT, industrial networks, etc.); A6: Lifecycle management of production-related Data, Information and Knowledge (DIK) (collection, storage, processing, analysis, backup, reuse and deletion of DIK); A7: Anticipatory and prescriptive decision making related to production; A8: Virtualization and cloud services; A9: Management of product innovation, process and organization; A10: Other.

Figure 15 - Skills development/training

As a conclusion from the information provided by the questions dedicated to the production process, it is important to highlight that:

- Few companies respond to changes in the production process autonomously/automatically and in real-time, which indicates that some companies have not yet adopted the spirit of industry 4.0 and there is a real potential for development in their production process.
- Few companies have been interested in involving industry 4.0 solution that few companies have been interested in adopting industry 4.0 solutions and no company has tried to use industry 4.0 solutions.
- There is no significant common priority or importance attributed to a given production process to be transformed by a digitalization project.
- Until now there is no company that has finished the adoption and the implementation of an Industry 4.0 project.
- There are no significant common practices regarding skills development and training.

5.4. Quality 4.0

The question QQ1 aims to know which practices in quality are currently deployed in the observed companies. Results of the survey reveal that most companies (35%) are based on a periodic inspection with conclusions based solely on the expertise of the inspector/quality controller and 35% follow a periodic inspection with conclusions based on both the expertise of an inspector/quality controller and data collected by sensors or measuring instruments. Only 24% adopt a real-time monitoring of industrial assets and production, with real-time alerts defined according to pre-established rules. Nevertheless, 6% of companies are based on real-time monitoring with alerts based on predictive analysis techniques, such as regression analysis.

The second question, QQ3, is focused on the technologies that are deployed in the different quality processes. According to Figure 16 (QQ3), we deduce that many companies, around 18%, are using computer-aided quality solutions, collaborative solutions (18%) and predictive solutions and business intelligence (16%). Recent technologies such as IoT, Mobile solutions and VR are rarely used i.e., equal of less than 10% of companies.

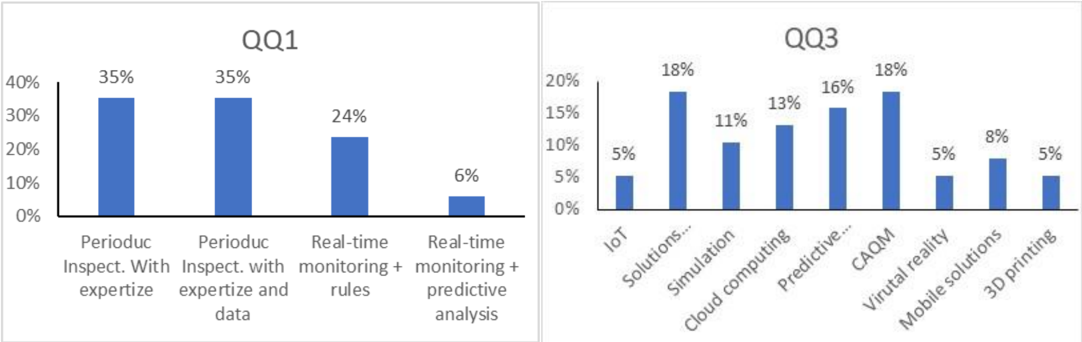


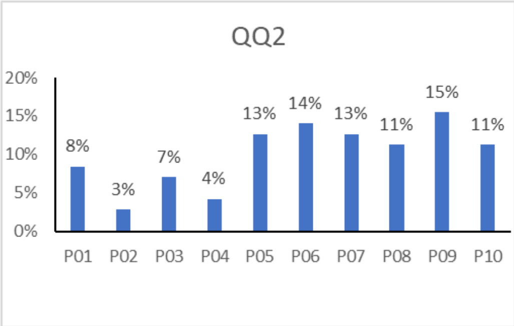
Figure 16 – The As is for Quality 4.0

The questions QQ2 and QQ4 and QQ6 aim to provide information about the interest of companies to I4.0 and future digitalisation projects in Quality.

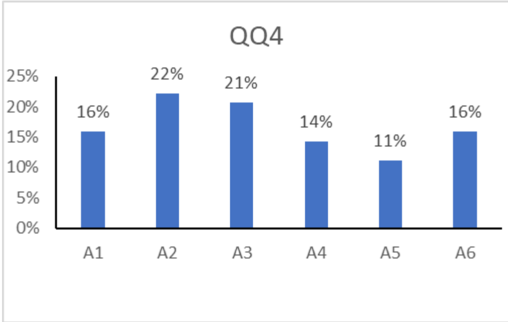
The question QQ2 asks for if companies "have thought about the quality processes that could be digitized in the organization?". Responses of observed companies presented in Figure 17 show that they are significantly dispersed. There is no significant common priority or importance. Nevertheless, most companies, which represent only 16%, have declared that they plan to conduct an industry 4.0 project to transform Data acquisition, inspection and diagnostic processes (P06), in Processes for sharing quality data, vertical and horizontal integration with other departments and stakeholders (P07, 13%), to Complaint collection, analysis and handling processes (P08, 11%) and in Quality audit process (P09, 15%).

The Question QQ4 focus on the scope of a future quality 4.0 project. According to Figure 17 (QQ4), we deduce that the most companies, 22%, reveals that they adopt the strategy of optimization of quality control steps during product industrialization (A2). Also 21% of companies apply the quality control during the manufacturing phases (in-process) (A3). 16 % of companies indicate that they consider the quality control steps during product design (A1). The same proportion of companies responded that they adopt a quality control strategy during the first stages of operation at the customer's premises (A5). Around 14% of companies declared that they are based on an application of post manufacturing quality control and before batch release (A4) and finally, few companies, around 12%, consider a product quality control in the medium/long term.

Concerning the question QQ6: If you are planning to launch a new Industry 4.0 project, how far along is your Industry 4.0 project deployment? Reponses show that only 31% of companies have already launched a Pilot project or adopted/have integrated a project. Nevertheless, the majority of companies (52%) are already in the study, planning and evaluation phase. Also, 14% of companies declare that they have launched the first initiatives and first commercial impacts.



P01: Strategic Analysis Process; P02 - Stakeholder Communication Process; P03: Quality planning process; P04 - Quality staff training and qualification process; P05: Quality sampling, control and planning process; P06: Data acquisition, inspection and diagnostic processes; P07: Processes for sharing quality data, vertical and horizontal integration with other departments and stakeholders ; P08: Complaint collection, analysis and handling processes; P09: Quality audit process; P10: Performance management processes, dashboards and business intelligence



A1: Design of quality control steps during product design; A2: Optimization of the quality control steps during the industrialization of the product; A3: Application of quality control during the manufacturing phases (in-process); A4: Application of quality control post manufacturing and before batch release; A5: Application of quality control during the first stages of operation at the customer's premises; A6: Application of product quality control in the medium/long term.

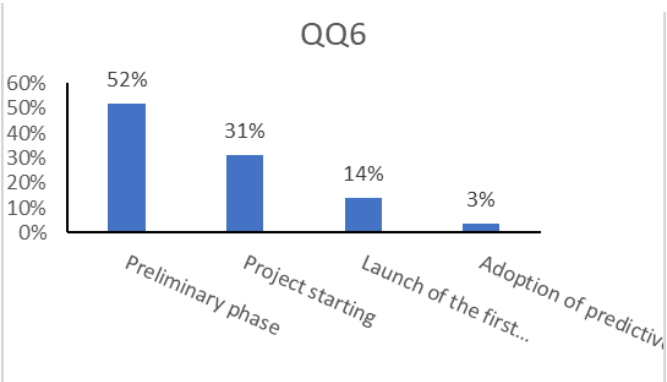
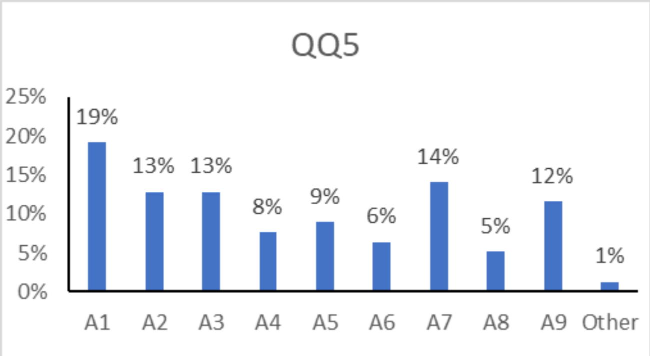


Figure 17 – Interest to I4.0 and future digitalisation projects

Next, we provide in Figure 18 responses to a question asked to know how companies react to Skills development and training for Quality 4.0. Thus, we have asked a question to know what employees skills in the organization need to be improved for digital quality transformation. According to the responses of companies, we deduce that the responses are dispersed and there is no a common practice. Nevertheless, 19% of respondents, say that there is a need to enhance the design, development and management of automated production systems (A1). 13% of companies declared that it is the Design, development and implementation of integrated systems and architectures which need be improved (A3). Same as for the management of product, process and organizational innovation (A9). The other responses are relatively not important for the observed companies.



A1: Design, development and management of automated production systems (industrial automation; robotics; etc.); A2: Innovative design/manufacturing (new processes; intelligent materials/products; eco-design; etc.); A3: Design, development and implementation of integrated systems and architectures (horizontal integration; vertical integration; integrated intelligence); A4: Development and piloting of collaborative, cooperative, autonomous/emergent applications and systems (Human-Computer Interaction; Machine-Machine Interaction; User-centered design); A5: Deployment of agile and intelligent connectivity solutions (IoT, industrial networks, etc.);A6: Data, Information and Knowledge (DIK) lifecycle management related to quality (collection, storage, processing, analysis, backup, reuse and deletion of DIK); A7: Anticipatory and prescriptive decision making related to quality; R8: Virtualization and cloud services; A9: Product, process and organizational innovation management A10: Other, define

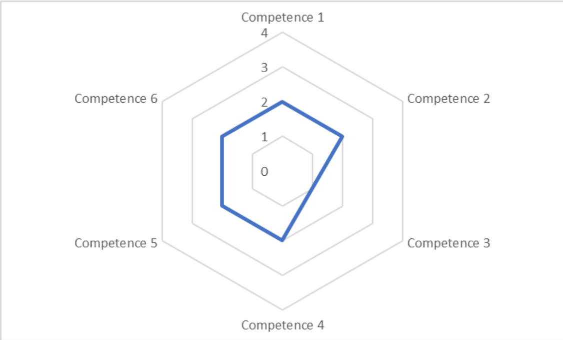
Figure 18 – Skills development/training

Thus, based on the analysis of responses of questions dedicated to the Quality process, it is important to highlight that:

- Most companies are based on the quality process on a periodic inspection and there is no company is based on real-time monitoring with alerts based on predictive analysis techniques.
- Most companies are based on Computer-aided quality solutions or collaborative solutions. Only less than 10% of companies adopt predictive solutions and business intelligence, IoT or VR for quality inspection.
- The questions about the interest of companies in I4.0 and future digitalization projects in Quality and for skills development/training show that there is no significant common priority or strategy for observed companies.

6. Curricula and Gap analysis in PC

For the gap analysis, three types of charts are made. The first is for the visualization of the level of coverage of competencies for each program. For example, the Figure 19 illustrates the level of coverage of such competencies for two engineering programs (E1 and E5) and two master programs (M1 and M3). As it may be noted, the level of coverage is different from a program to another, and this may be justified by the nature of the program and the targeted scientific area (like E5 and M1).



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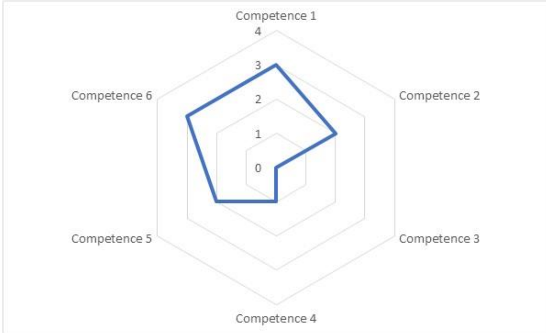

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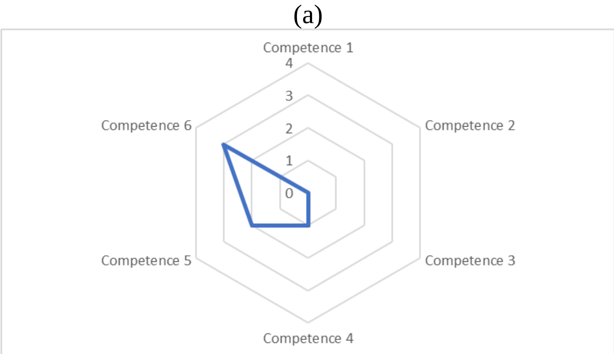

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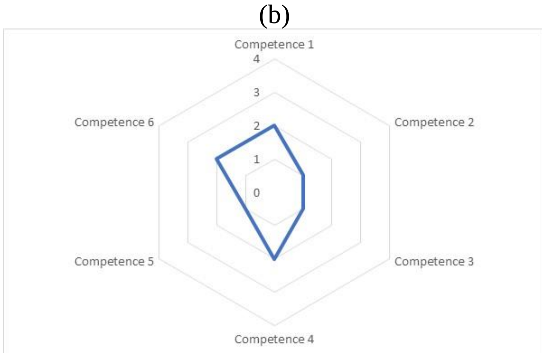
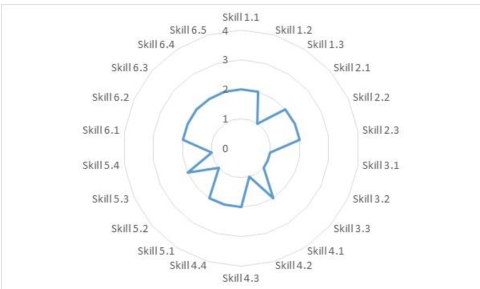


(d)

Figure 19 – Level of coverage of competencies for the four programs E1 (a), E5 (b), M1(c) and M3(d)

We have also analyzed the level of coverage of skills. Figure 20 shows the level of coverage of the same four programs (E1, E5, M1 and M3). As it can be noted, different skills are not covered by many programs. Also, many skills are not covered, such as skills 13.1, 3.2, and 5.4. Nevertheless, Skills 5.3 and 6.3 are well covered with the level 3 for M1. For a better analysis of programs, a deeper analysis is required. Therefore, we analyzed how technologies are addressed in the different programs.



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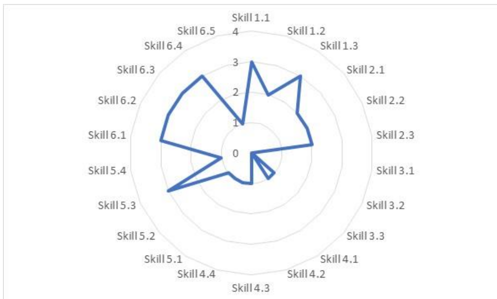

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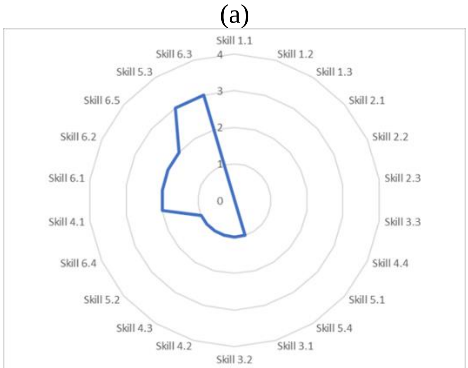

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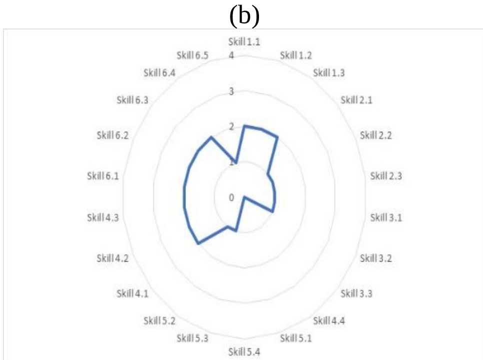
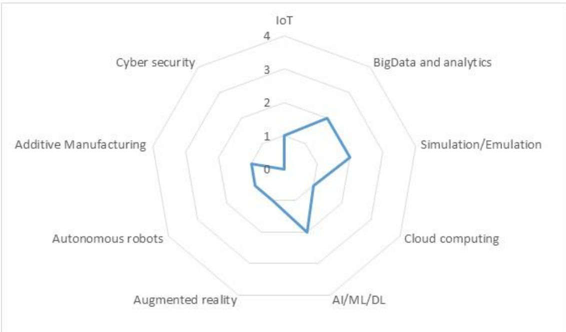


(d)

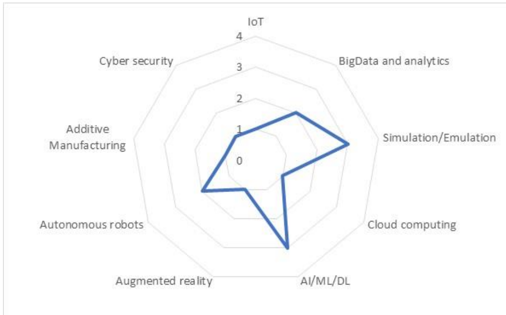
Figure 20 – Level of coverage of skills for the four programs E1 (a), E5 (b), M1(c) and M3(d)

Considering the technologies 4.0, we noticed that the common technologies adopted in most of the programs are IoT, Big data and analytics and AI/ML/DL but with a low level of coverage of 2. Technologies such as Cloud computing, Augmented reality, Autonomous robots and Cyber security are not well addressed (below requirements) (see Figure 21).

After the analysis of collected data, the gap between levels acquired and levels targeted for both skills and technologies for each program are analyzed. It is important to note that the AS-IS level is calculated based on collected data for these curricula while the TO-BE is defined by local teachers for each curricula coordinator. This analysis reveals that many MPQ4.0 related technologies and skills are not well covered in all programs. To fit with the requirement of MPQ4.0, the syllabus of some courses should be revised. This analysis is confirmed by the targeted level for technologies (see Figure 22). Indeed, new technologies should be considered in all programs in the different MPQ4.0 topics such as Augmented reality, cloud computing or Cloud computing or cybersecurity. Moreover, the targeted level of coverage of some of already existing technologies has to be improved (from the level 1 to level 3) such as Artificial intelligence, additive manufacturing and big data analytics. Similarly to technologies, the level of coverage of already addressed skills should be upgraded (from 1 and 2 to 3) (see Figure 22).



(a)



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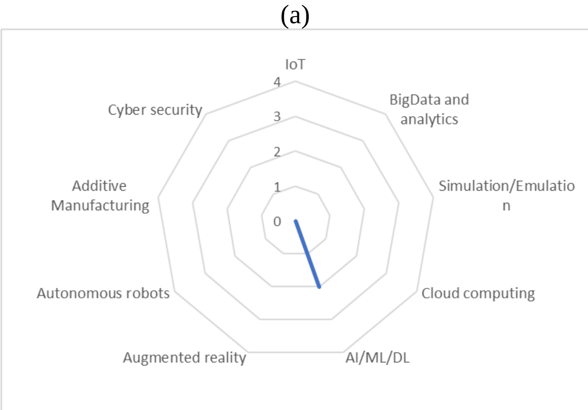

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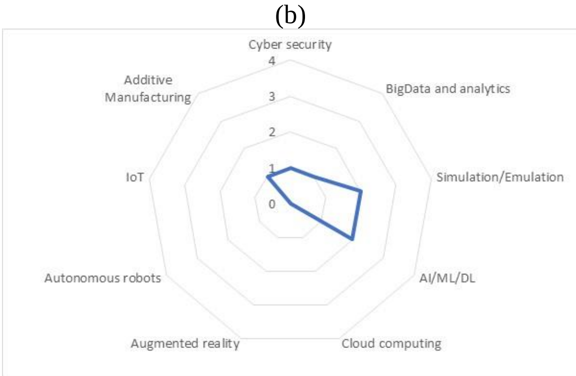

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Figure 21 – Level of coverage of technologies for the four programs E1 (a), E5 (b), M1(c) and M3(d)

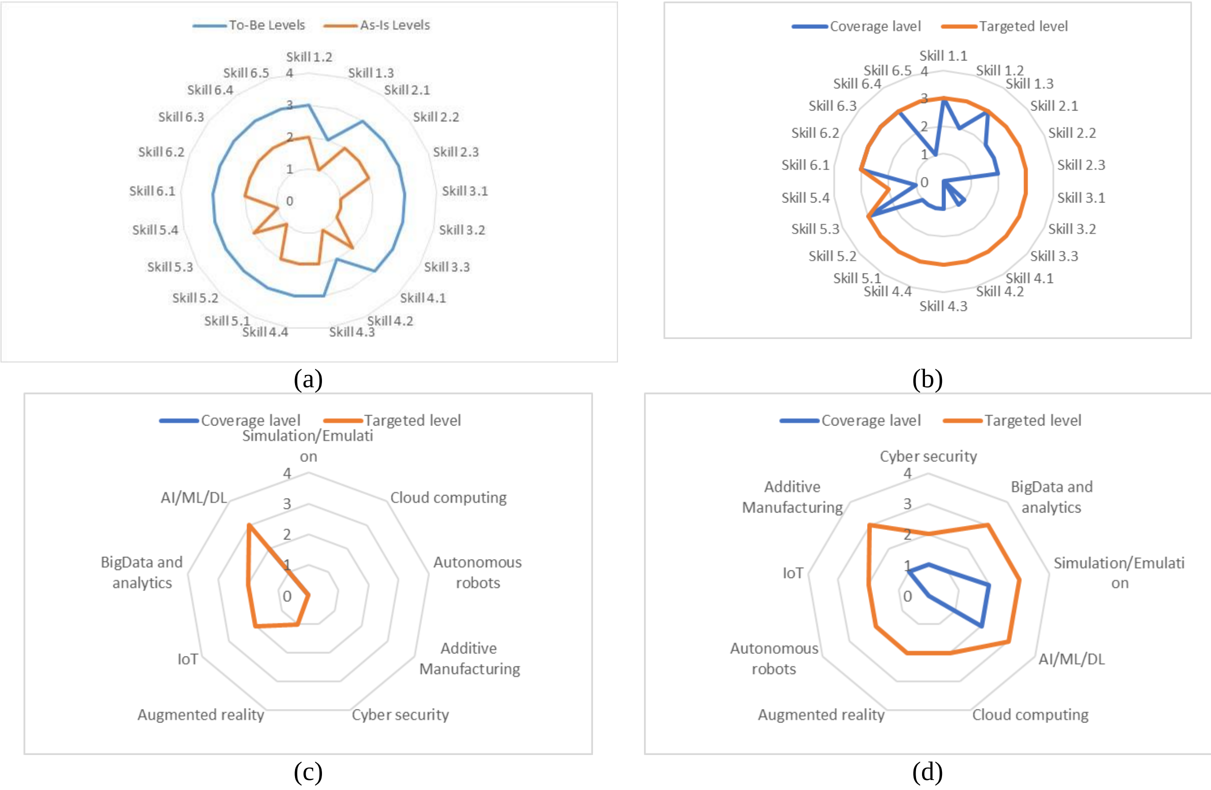

Figure 22 – Covered vs targeted skills (programs E1 (a), E5 (b)) and technologies (programs M1(c) and M3(d))

To analyze the gap between the "industrial needs and their interest to digitalization" and the "identified gap between MPQ4.0 skills and those taught in existing curricula", Figure 23 shows the suggested cross-analysis methodology. In this methodology, the analysis of the surveys permits the identification of processes related to maintenance, production and quality that local industry needs to develop through future digitalization projects. It allows the identification of the main MPQ4.0 technologies already used by local industry and those that need future development. From another perspective, the analysis of existing curricula enables the identification of both skills and technologies that need to be developed, independently from the addressed topic (Maintenance, production or quality).

7. Cross analysis and recommendations

This section aims to present the suggested cross-analysis between the "industrial needs and their interest to digitalization" and the "identified gap between MPQ4.0 skills and those taught in existing curricula". The identification of the needs of the 32 Tunisian and Moroccan companies was carried out using the survey presented in section 3.2.1 and appendix 1 (see section 9).

The suggested cross-analysis methodology is illustrated in Figure 23. In this methodology, the analysis of the surveys permits the identification of processes related to maintenance, production and quality that local industry needs to develop through future digitalization projects. It allows the identification of main MPQ4.0 technologies already used by local industry and those that need future development. From another perspective, the analysis of existing curricula allows the identification of both skills and technologies that need to be developed, independently from addressed topic (Maintenance, production or quality). The final step in the methodology is the cross-analysis which consists in presenting the MPQ4.0 processes/technologies matrix. This matrix is very important as it will be used for future tasks such as T1.3, T2.1, T2.2, T2.3 and T2.4.

The results of data analysis of the surveys show that different processes should be developed in the industry:

- For maintenance: Most of the companies have highlighted the importance of developing predictive/preventive maintenance and real-time monitoring of maintenance tasks. With regards to technologies, only "basic" technologies are used. Therefore, most of MPQ related technologies needs to be integrated in future digitalization projects.
- For production: There is no significant common priority or importance according to companies. Nevertheless, the identified processes are "Planning and scheduling", "inventory management" and "production monitoring". Moreover, technologies that must be developed are IoT, simulation, Cloud computing, predictive solutions and 3D printing.
- For quality: Similarly to production, there is no significant common priority or importance according to companies. However, the identified processes that need to be developed are the "in-process product quality control" and "post-production quality control". These processes require real-time monitoring with predictive analysis. Moreover, technologies that must be developed are IoT, VR, and the use of mobile solutions.

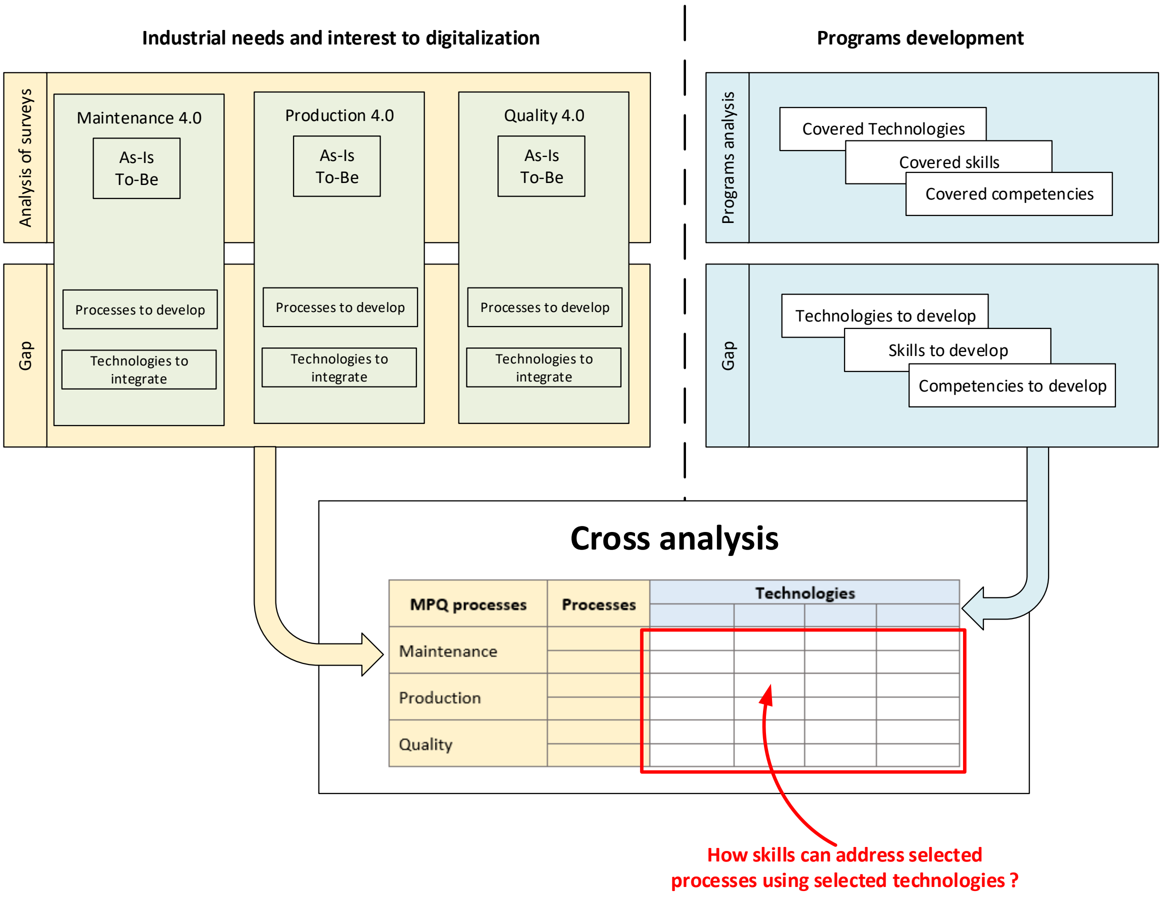

Figure 23 – Cross analysis cross-analysis of the identified needs (industrial and academic)

From academic perspective, the analysis of the 6 curricula reveals that most of technologies are targeted by different PC universities as shown in **Erreur ! Source du renvoi introuvable.**. We noted that those that have particularly highlighted are: BigData, IoT, Augmented and Virtual Reality, Autonomous Robots, Cloud computing, Artificial Intelligence and finally Simulation. Each of the 9 technologies initially considered the surveys were crossed with the ones identified by PC universities.

This cross-analysis reveals this list of technologies that require more development in this project, and which are: Artificial Intelligence/ML/DL, IoT, Cloud computing and BigData, Virtual Reality and Simulation.

With regards to competences and skills, most of them are already covered by the 8 curricula, the level of coverage should be improved.

The result of this cross-analysis is the MPQ4.0 processes/technologies matrix is shown in Table 1. This matrix represents the required development that should be undertaken during this project based on the collected data and their analysis. For each process/technology pair, the skills that should be developed are highlighted in Table 1.

In summary, this analysis conducted in task 1.2 and detailed in this deliverable shows the interest of both PC companies and universities to the digitalization of MPQ processes. Some of the local companies have already started a project to transform some of the existing processes. Although this interest in Industry 4.0 technologies, and to MPQ4.0 particularly, we have noted that there is a weak University-Industry collaboration in topics related to MPQ4.0. Hence, most of the companies have highlighted the lack of such cooperation as most of the training are conducted by other training organization. Therefore, more effort should be made to strengthen this cooperation which represents one of the objectives of ENHANCE. Indeed, ENHANCE aims to contribute to strengthening University-Industry collaboration.

The cross-analysis made in this task and the obtained MPQ4.0 processes/technologies matrix are very useful for the development of training and teaching materials in Tasks 2.1, 2.2, 2.3 and 2.4. In this context, and based on the gap analysis, we suggest the following training activities. For example, for the topic maintenance, we suggest the list of training activities of Table 2. Readers may note that a new process (corrective maintenance) is added to maintenance in addition the preventive and predictive maintenance based on its relevance as discussed in Deliverable D1.1.

In addition, the suggested training activities for production 4.0 and quality 4.0 are presented in Table 3 and Table 4. As for maintenance, a new process (quality management) in added to quality based on our literature analysis conducted in Deliverable D1.1.

Table 1 – MPQ4.0 processes/technologies matrix

MPQ4.0 topics	Processes	Technologies								
		AI/ML/DL	IoT	Cloud Computing	BigData	Virtual Reality	Simulation	Autonomous robots	Additive Manufacturing	Cyber security
Maintenance	Predictive maintenance	Skill 1.2 Skill 6.1 Skill 6.2 Skill 6.3 Skill 6.4 Skill 6.5	Skill 1.3 Skill 3.1 Skill 3.2 Skill 3.3 Skill 4.3	Skill 1.3 Skill 4.3 Skill 5.1	Skill 1.3 Skill 4.3 Skill 5.1 Skill 5.2 Skill 5.3	Skill 1.3 Skill 2.1 Skill 4.3	Skill 1.3 Skill 4.3	Skill 2.2 Skill 2.3 Skill 3.3 Skill 4.3	Skill 4.2	Skill 1.2 Skill 3.1 Skill 5.1 Skill 5.4
	Preventive maintenance	Skill 6.1 Skill 6.2 Skill 6.3 Skill 6.4 Skill 6.5	Skill 1.3 Skill 3.1 Skill 3.2 Skill 3.3 Skill 4.3	Skill 1.3 Skill 4.3 Skill 5.1	Skill 1.3 Skill 4.3 Skill 5.1 Skill 5.2 Skill 5.3	Skill 1.3 Skill 2.1 Skill 4.3	Skill 1.3 Skill 4.3	Skill 2.2 Skill 2.3 Skill 3.3 Skill 4.3	Skill 4.2	Skill 1.2 Skill 3.1 Skill 5.1 Skill 5.4
Production	Planning and scheduling	Skill 6.1 Skill 6.2 Skill 6.3 Skill 6.4 Skill 6.5	Skill 1.3 Skill 3.1 Skill 3.2 Skill 3.3 Skill 4.3	Skill 1.3 Skill 4.3 Skill 5.1	Skill 1.3 Skill 4.3 Skill 5.1 Skill 5.2 Skill 5.3	Skill 1.3 Skill 2.1 Skill 4.3	Skill 1.3 Skill 4.3	Skill 2.2 Skill 2.3 Skill 3.3 Skill 4.3	Skill 4.2	Skill 1.2 Skill 3.1 Skill 5.1 Skill 5.4
	Inventory management	Skill 6.1 Skill 6.2 Skill 6.3 Skill 6.4 Skill 6.5	Skill 1.3 Skill 3.1 Skill 3.2 Skill 3.3 Skill 4.3	Skill 1.3 Skill 4.3 Skill 5.1	Skill 1.3 Skill 4.3 Skill 5.1 Skill 5.2 Skill 5.3	Skill 1.3 Skill 2.1 Skill 4.3	Skill 1.3 Skill 4.3	Skill 2.2 Skill 2.3 Skill 3.3 Skill 4.3	Skill 4.2	Skill 1.2 Skill 3.1 Skill 5.1 Skill 5.4
	Production monitoring and control	Skill 6.1 Skill 6.2 Skill 6.3 Skill 6.4	Skill 1.3 Skill 3.1 Skill 3.2 Skill 3.3	Skill 1.3 Skill 4.3 Skill 5.1	Skill 1.3 Skill 4.3 Skill 5.1 Skill 5.2	Skill 1.3 Skill 2.1 Skill 4.3	Skill 1.1 Skill 1.3 Skill 4.3	Skill 2.2 Skill 2.3 Skill 3.3 Skill 4.3	Skill 4.2	Skill 1.2 Skill 3.1 Skill 5.1 Skill 5.4

		Skill 6.5	Skill 4.3		Skill 5.3					
Quality	In-process product quality control	Skill 6.1 Skill 6.2 Skill 6.3 Skill 6.4 Skill 6.5	Skill 1.3 Skill 3.1 Skill 3.2 Skill 3.3 Skill 4.3	Skill 1.3 Skill 4.3 Skill 5.1	Skill 1.3 Skill 4.3 Skill 5.1 Skill 5.2 Skill 5.3	Skill 1.3 Skill 2.1 Skill 4.3	Skill 1.1 Skill 1.3 Skill 4.3	Skill 2.2 Skill 2.3 Skill 3.3 Skill 4.3	Skill 4.2	Skill 1.2 Skill 3.1 Skill 5.1 Skill 5.4
	Post-production quality control	Skill 6.1 Skill 6.2 Skill 6.3 Skill 6.4 Skill 6.5	Skill 1.3 Skill 3.1 Skill 3.2 Skill 3.3 Skill 4.3	Skill 1.3 Skill 4.3	Skill 1.3 Skill 4.3 Skill 5.1 Skill 5.2 Skill 5.3	Skill 1.3 Skill 2.1 Skill 4.3	Skill 1.1 Skill 1.3 Skill 4.3	Skill 2.2 Skill 2.3 Skill 3.3 Skill 4.3	Skill 4.2	Skill 1.2 Skill 3.1 Skill 5.1 Skill 5.4

Table 2 : Training activities of maintenance 4.0

Maintenance 4.0		
Corrective maintenance	**Preventive maintenance**	**Predictive maintenance**
Maintenance tools preparation, organisation and management	PM Task Lists	Identify critical assets
5S, SMED	Breakdown Costs	Establish a data base (CMM'I'S, …)
Organization and preparation of disassembly	Calculate the Standard Deviation (SD)	Analyse failure modes (RCM, FMEA, …)
Inspection, verification, sampling, measurement	Using MTBF for Failure Analysis	Implement CBM, PHM
Organization and preparation of reassembly	Specific CMMS Training	Develop predictive models and algorithms
XR for disassembly, inspection/verification and assembly	PM Reliability Enhancement: FMECA, Reliability Centered Maintenance to PPM, PM Optimization, etc.	Deploy to pilot equipment
Refurbishment	Sustainability driven maintenance	Real-time communication
Restart and Ramp up after breakdown	CMMS dashboards and reporting functions	Big data processing and modelling techniques
Design of Experiments (DOE) to optimize system parameters for restart/ramp up	Maintenance planning and scheduling	Downtime forcast and optimal maintenance planning
	Total Productive Maintenance and Industry 4.0 technologies	Data acquisition in industry 4.0
		Predictive maintenance sensors and implementation

Table 3 : Training activities of Production 4.0

Production 4.0		
Planning and scheduling	**Inventory management**	**Production monitoring and control**
Planning and scheduling techniques	Finance, Supply Chain, Procurement, Customer Service, Warehouse Management	Real-time DAQ
Master Production Scheduling (MPS)	Cloud-based inventory management : process, classification, system parameters and system review	Knowledge-based systems
Capacity and materials requirement Planning	Demand planning and forecasting techniques and models	Data fusion and analytics
Emerging uses of smart technologies for production	Big data and predictive inventory analytics	IoT/CPS development and integration
Horizontal and vertical integration & Workflow management	Business process, KPI & Reporting	Interoperability, visibility, connectivity,
Design and development of smart Production Planning/Scheduling systems and processes	Inventory management dashboards	distributed / digital control systems (DCSs)
Planning and scheduling techniques in industry 4.0 and cloud manufacturing	Inventory locating tracking and moving	PLM and Digital Factory to model and act the physical system
Data-driven planning/scheduling models and algorithms		Lean production under Industrie 4.0 paradigm
Cyber Physical Production Systems design, assessment, evaluation models and security		Automated Value Srteam Mapping
Digital transformation in production planning and scheduling		Design of facility layout for Indusry 4.0

Table 4 : Training activities of Quality 4.0

Quality 4.0		
In-process product quality control	**Post-manufacturing quality control**	**quality management**
Non-Conformities RCA and Quality gates design	Metrology Basics: metrology, inspection, accuracy and precision, etc.	Digitalisation of quality management system
Sensor's sensitivity analysis: digital, analogical	Generic quality control tools	business process management
Sensors network setup and data accumulation	Standards and Comparators: Line Standards, End Standards, Slip Gauges or Johannsen Gauges	Quality Planning, Quality Control, QM – Functions
QC model design	The use of comparators	Integration materiel management, Production Planning ,sales and distribution, …
Sensors network risks	Measurement of surface Finish	Master Data
Resilience by design	Machine Tool Testing: Alignment Tests on Lathe, Milling, Drilling machines	Inspection Methods, sampling, Inspection Plan
Operational excellence 4.0	Process maturity self-assessment	Quality Info Records ,Lot Inspection, Result Recording, Usage Decision
	Integrated thinking system modelling and development	
	Digitalization of Holistic Quality - Describing a holistic, integrated, system-wide approach	
	Integrating Lean Manufacturing into Industry 4.0 – JIT, Kanban, TPM concepts in Industry 4.0	
	Performance ongoing improvement	

8. References

Industrial and Systems Engineering Body of Knowledge, Institute of Industrial and Systems Engineers, 2021.

Rüßmann, M.,et al., Industry 4.0: The future of productivity and growth in manufacturing industries. Boston Consulting Group (BCG), pp.1-14, 2015.

D1.1. Literature review about required skills related to MPQ4.0, ENHANCE project, 2021

9. Appendix 1: industrial survey

Questionnaire Maintenance, Production et Qualité - MPQ 4.0

Nom de l'entreprise (optionnel)	:………………………………………………
Secteur d'activité	:………………………………………………
Taille de l'entreprise (nombre d'employés)	:………………………………………………

1. Contexte

Ce sondage s'inscrit dans le cadre du projet intitulé « strENgtHening skills and training expertise for TunisiAN and MorroCan transition to industry 4.0 Era / ENHANCE » (http://eplus-enhance.eu/) qui est un projet co-financé par la commission européenne. ENHANCE vise à :

- Réduire l'écart entre les compétences acquises dans les établissements d'enseignement supérieur et les compétences requises par les industries tunisiennes et marocaines en MPQ4.0.
- Proposer un cadre d'apprentissage MPQ4.0 et développer du matériel pédagogique innovant en utilisant une méthodologie d'apprentissage centrée of l'apprenant.
- Créer une plateforme d'apprentissage tout au long de la vie et deux Hubs d'Innovation Digitale, un en Tunisie et un au Maroc.

2. Objectif du questionnaire

Ce questionnaire vise à collecter les besoins et les préoccupations actuelles des industriels tunisiens et marocains en projets de transformations digitales en Maintenance, Production et Qualité (MPQ) dans l'ère de l'industrie 4.0. Ainsi, l'objectif est de promouvoir les pistes de développement des infrastructures d'innovation pédagogique (DIH) et d'orienter la mise à jour des contenus de formations pour bâtir les compétences en MPQ 4.0.

Le questionnaire est constitué de 20 questions, réparties comme suit :

- **Les défis de la digitalisation et la formation de collaborateurs en MPQ4.0: 2 questions**
- **Maintenance : 6 questions**
- **Production : 6 questions**
- **Qualité : 6 questions**

3. Les défis de la digitalisation et la formation de collaborateurs en MPQ4.0

MPQ.Q1 : Pour votre organisation, citer les 3 défis ou obstacles les plus importants des initiatives de digitalisation des processus MPQ? (Plusieurs choix sont possibles)

- ☐ Manque de technologies et d'infrastructures adaptées en interne
- ☐ Difficultés pour asofer une formation continue des collaborateurs
- ☐ Capabilité à repenser les processus MPQ après changement/digitalisation
- ☐ Résistance aux changements organisationnels
- ☐ Réticences face aux difficultés techniques et technologiques, et face à un déploiement à grande échelle
- ☐ Réticences par rapport à la sécurité et la confidentialité des données
- ☐ Difficultés (expertise, coût) à recruter des compétences humaines en externe
- ☐ Manque de moyens financiers (coût d'acquisition, de déploiement, d'opérationnalisation et de maintenance des nouvelles technologies)

MPQ.Q2 : Comment vos employés sont formés aux nouvelles technologies/pratiques de l'industrie 4.0? (Plusieurs choix sont possibles)

- ☐ Par des formations en ligne
- ☐ Par des organismes externes (centre de formation, centres de transfert technologique, etc.)
- ☐ Auto-formation
- ☐ Partage d'expériences
- ☐ Par des partenariats avec les institutions d'enseignement supérieur (écoles d'ingénieurs, etc.)
- ☐ Autre

4. Maintenance 4.0 (6 questions)

MQ1 : Dans votre organisation, parmi les pratiques suivantes de maintenance, laquelle est actuellement déployée ? (Plusieurs choix sont possibles)

- ☐ Inspection périodique avec conclusions basées uniquement of l'expertise de l'inspecteur
- ☐ Inspection périodique avec conclusions basées à la fois of l'expertise d'un inspecteur et of des données recueillies par des instruments de meofe
- ☐ Suivi en temps réel des actifs industriels, avec des alertes en temps réel, définies selon des règles préétablies
- ☐ Suivi en temps réel avec des alertes définies selon des techniques d'analyse prédictive, par exemple une analyse de régression

MQ2 : avez-vous mené une réflexion of la stratégie de changement du modèle de gestion de la maintenance dans votre organisation ? (Plusieurs choix sont possibles)

- ☐ Maintenance corrective → préventive : pour certains ou tous les équipements, on cherche à se prémunir des arrêts intempestifs en programmant des arrêts à intervalles réguliers
- ☐ Maintenance corrective → prédictive : pour certains ou tous les équipements, on cherche à se prémunir des arrêts intempestifs en déterminant le meilleur moment d'arrêter l'équipement

- ☐ Maintenance préventive → prédictive : pour certains ou tous les équipements, on cherche à optimiser la capacité, la disponibilité et la fiabilité de l'équipement en minimisant les temps d'arrêts intempestifs et programmés
- ☐ Aucune réflexion en cours

MQ3 : Comptez-vous mener prochainement un projet d'industrie 4.0 pour la transformation de certains des processus de maintenance suivants ? Lesquels ? (Plusieurs choix sont possibles)

- ☐ P01 - Processus de formation et de qualification des opérateurs de maintenance
- ☐ P02 - Processus de gestion des stocks de pièces de rechange et d'outillages de maintenance
- ☐ P03 - Processus de planification de la maintenance
- ☐ P04 - Processus d'intervention de maintenance
- ☐ P05 - Processus d'acquisition de données, d'inspection et de diagnostic
- ☐ P06 - Processus de partage de données de maintenance, d'intégration verticale et horizontale avec les autres services et parties prenantes
- ☐ P07 - Processus d'évaluation de durée de vie et d'état de santé des équipements
- ☐ P08 - Processus d'évaluation de vieillissement et d'estimation de durée de vie restante (RUL)
- ☐ P09 - Processus d'extension et de rallonge de durée de vie
- ☐ P10 - Processus de gestion de fin de vie des équipements (décommissionnement, re convertissement, vente)
- ☐ P11 - Processus de gestion de la performance de la maintenance

MQ4 : Parmi ces technologies, lesquelles sont déployées dans les différents processus de maintenance (plusieurs choix sont possibles)

- ☐ Internet industriel des objets
- ☐ Solutions collaboratives
- ☐ Simulation
- ☐ Le cloud, la supervision ou la télémaintenance
- ☐ Solutions prédictives et informatique décisionnelle
- ☐ Solutions de maintenance assistée par ordinateur
- ☐ Réalité Étendue : réalité augmentée (AR), réalité mixte (MR) ou réalité virtuelle (VR)
- ☐ Solution de mobilité (tablette, smartphone, etc.)
- ☐ Impression 3D
- ☐ Aucune

MQ5 : Étant donné le potentiel d'amélioration des processus de maintenance, où en est le déploiement de la maintenance prédictive au sein de votre organisation? (1 seul choix possible)

- ☐ Phase d'étude de faisabilité et de planification
- ☐ Lancement de projets pilotes de maintenance prédictive
- ☐ Lancement des premières initiatives de maintenance prédictive ET premiers impacts commerciaux
- ☐ Adoption de stratégies de maintenance prédictive et intégration à l'échelle de l'entreprise

☐ Pas encore envisagé

MQ6 : Quelles sont les compétences humaines de votre organisation qui doivent être améliorées pour la transformation digitale de la maintenance ? (plusieurs choix sont possibles)

- ☐ Conception, développement et mise en œuvre de systèmes et d'architectures intégrées (Intégration horizontale ; Intégration verticale ; Intelligence intégrée)
- ☐ Développement et pilotage d'applications et de systèmes collaboratifs, coopératifs, autonomes/émergents (Interaction Homme-Machine ; Interaction Machine-Machine ; Conception centrée utilisateur)
- ☐ Déploiement de solutions de connectivité agiles et intelligentes (IoT, réseaux industriels, etc.)
- ☐ Gestion du cycle de vie des Données, Informations et Connaissances (DIK) liées à la maintenance (collecte, stockage, traitement, analyse, sauvegarde, réutilisation et suppression des DIK)
- ☐ Prise de décision anticipée et prescriptive liée à la maintenance
- ☐ Virtualisation et services infonuagiques (Cloud)
- ☐ Management de l'Innovation produit, processus et organisation
- ☐ Autre, définir

5. Production 4.0

PQ1 : Les processus de production sont-ils (plusieurs choix sont possibles)**:**

- ☐ Bien définis,
- ☐ Standardisés
- ☐ Interconnectés et communicants
- ☐ Répondant de manière autonome/automatique et en temps réel aux changements
- ☐ Analysés périodiquement
- ☐ Digitalisés

PQ2 : Pour votre production, quels sont les processus qui ont été transformés par une solution de l'industrie 4.0 ? (Plusieurs choix sont possibles)

- ☐ P01 - Processus Conception & Développement
- ☐ P02 - Processus Gestion des besoins (prévisions et/ou commandes clients)
- ☐ P03 - Processus Gestion de stock et approvisionnement
- ☐ P04 - Processus Planification
- ☐ P05 - Processus Ordonnancement
- ☐ P06 - Processus Réalisation du produit (Fabrication)
- ☐ P07 – Processus gestion des ressources (humaines et matérielles)
- ☐ P08 – Processus Suivi de la production
- ☐ Autre, Précisez

PQ3 : Parmi ces technologies, lesquelles sont déployées dans les différents processus de production (plusieurs choix sont possibles)

- ☐ Internet industriel des objets
- ☐ Solutions collaboratives
- ☐ Simulation
- ☐ Le cloud, la supervision ou la télémaintenance
- ☐ Solutions prédictives et informatique décisionnelle
- ☐ Solutions de maintenance assistée par ordinateur
- ☐ Réalité Étendue : réalité augmentée (AR), réalité mixte (MR) ou réalité virtuelle (VR)
- ☐ Solution de mobilité (tablette, smartphone, etc.)
- ☐ Impression 3D

PQ4 : Comptez-vous mener prochainement un projet d'industrie 4.0 pour la transformation de certains des processus de production suivants ? Lesquels ? (Plusieurs choix sont possibles)

- ☐ P01 - Processus Conception & Développement
- ☐ P02 - Processus Gestion des besoins (prévisions et/ou commandes clients)
- ☐ P03 - Processus Gestion de stock et approvisionnement
- ☐ P04 - Processus Planification
- ☐ P05 - Processus Ordonnancement
- ☐ P06 - Processus Réalisation du produit (Fabrication)
- ☐ P07 – Processus gestion des ressources (humaines et matérielles)
- ☐ P08 – Processus Suivi de la production
- ☐ Autre, Précisez

PQ5 : Si vous comptez lancer un nouveau projet d'industrie 4.0, où en est le déploiement de votre projet d'industrie 4.0 ? (Un seul choix est possible)

- ☐ Phase d'étude, de planification et d'évaluation
- ☐ Lancement d'un projet pilote
- ☐ Lancement des premières initiatives ET premiers impacts commerciaux
- ☐ Adoption du projet et intégration à l'échelle de l'entreprise

PQ6 : Quelles sont les compétences humaines de votre organisation **qui doivent être améliorées** pour la transformation digitale de la production ? (Plusieurs choix sont possibles)

- ☐ Conception, développement et pilotage de systèmes de production automatisés (automatisation industrielle; robotique ; etc.)
- ☐ Conception/fabrication innovantes (nouveaux procédés ; matériaux/produits intelligents; éco-conception ; etc.)
- ☐ Conception, développement et mise en œuvre de systèmes et d'architectures intégrées (Intégration horizontale; Intégration verticale; Intelligence intégrée)
- ☐ Développement et pilotage d'applications et de systèmes collaboratifs, coopératifs, autonomes/émergents (Interaction Homme-Machine ; Interaction Machine-Machine ; Conception centrée utilisateur)

- ☐ Déploiement de solutions de connectivité agiles et intelligentes (IoT, réseaux industriels, etc.)
- ☐ Gestion du cycle de vie des Données, Informations et Connaissances (DIK) liées à la production (collecte, stockage, traitement, analyse, sauvegarde, réutilisation et suppression des DIK)
- ☐ Prise de décision anticipée et prescriptive liée à la production
- ☐ Virtualisation et services infonuagiques (Cloud)
- ☐ Management de l'Innovation produit, processus et organisation
- ☐ Autre, définir

6. Qualité 4.0 (6 questions)

QQ1 : Dans votre organisation, parmi les pratiques suivantes de qualité, laquelle est actuellement déployée ? (Plusieurs choix possibles)

- ☐ Inspection périodique avec conclusions basées uniquement of l'expertise de l'inspecteur/contrôleur qualité
- ☐ Inspection périodique avec conclusions basées à la fois of l'expertise d'un inspecteur/contrôleur qualité et of des données recueillies par des capteurs ou des instruments de mesure
- ☐ Suivi en temps réel des actifs industriels et de la production, avec des alertes en temps réel, définies selon des règles préétablies
- ☐ Suivi en temps réel avec des alertes définies selon des techniques d'analyse prédictive, par exemple une analyse de régression

QQ2 : Avez-vous mené une réflexion of les processus qualité susceptibles d'être digitalisés dans votre organisation ? (plusieurs choix sont possibles)

- ☐ P01 – Processus d'analyse stratégique
- ☐ P02 – processus de communication avec les parties intéressées
- ☐ P03 – Processus de planification de la qualité
- ☐ P04– Processus de formation et de qualification des collaborateurs de la fonction qualité
- ☐ P05 – Processus d'échantillonnage, de contrôle et de planification de la qualité
- ☐ P06 – Processus d'acquisition de données, d'inspection et de diagnostic
- ☐ P07 – Processus de partage de données de qualité, d'intégration verticale et horizontale avec les autres services et parties prenantes
- ☐ P08 – Processus de collecte, d'analyse et de traitement des réclamations
- ☐ P09 – Processus d'audit de la qualité
- ☐ P10 – Processus de gestion de la performance, tableaux de bord et business intelligence

PQ3 : Parmi ces technologies, lesquelles sont déployées dans les différents processus de la qualité (plusieurs choix sont possibles)

- ☐ Internet industriel des objets
- ☐ Solutions collaboratives
- ☐ Simulation
- ☐ Le cloud, la supervision ou la télémaintenance
- ☐ Solutions prédictives et informatique décisionnelle
- ☐ Solutions de maintenance assistée par ordinateur

- ☐ Réalité Étendue : réalité augmentée (AR), réalité mixte (MR) ou réalité virtuelle (VR)
- ☐ Solution de mobilité (tablette, smartphone, etc.)
- ☐ Impression 3D

QQ4: Quelle serait le périmètre d'un futur projet qualité 4.0 ? (Plusieurs choix sont possibles)

- ☐ Conception des étapes de contrôle qualité lors de la conception du produit
- ☐ Optimisation des étapes de contrôle qualité lors de l'industrialisation du produit
- ☐ Application du control qualité durant les phases de la fabrication (in-process)
- ☐ Application du control qualité post fabrication et avant libération des lots
- ☐ Application du control qualité lors des premières étapes d'exploitation chez le client
- ☐ Application du control qualité produit à moyen/long termes

QQ5 : Quelles sont les compétences humaines de votre organisation **qui doivent être améliorées** pour la transformation digitale de la qualité? (plusieurs choix sont possibles)

- ☐ Conception, développement et pilotage de systèmes de production automatisés (automatisation industrielle; robotique ; etc.)
- ☐ Conception/fabrication innovantes (nouveaux procédés; matériaux/produits intelligents; éco-conception ; etc.)
- ☐ Conception, développement et mise en œuvre de systèmes et d'architectures intégrées (Intégration horizontale; Intégration verticale; Intelligence intégrée)
- ☐ Développement et pilotage d'applications et de systèmes collaboratifs, coopératifs, autonomes/émergents (Interaction Homme-Machine ; Interaction Machine-Machine ; Conception centrée utilisateur)
- ☐ Déploiement de solutions de connectivité agiles et intelligentes (IoT, réseaux industriels, etc.)
- ☐ Gestion du cycle de vie des Données, Informations et Connaissances (DIK) liées à la qualité (collecte, stockage, traitement, analyse, sauvegarde, réutilisation et suppression des DIK)
- ☐ Prise de décision anticipée et prescriptive liée à la qualité
- ☐ Virtualisation et services infonuagiques (Cloud)
- ☐ Management de l'Innovation produit, processus et organisation
- ☐ Autre, définir

QQ6 : Si vous comptez lancer un nouveau projet d'industrie 4.0, où en est le déploiement de votre projet d'industrie 4.0 ? (Un seul choix est possible)

- ☐ Phase d'étude, de planification et d'évaluation
- ☐ Lancement d'un projet pilote
- ☐ Lancement des premières initiatives ET premiers impacts commerciaux
- ☐ Adoption du projet et intégration à l'échelle de l'entreprise