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Enhance
Maintenance - Production - Quality

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D.2.2 Pilot 1: Maintenance 4.0

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Executive summary

This document introduces two courses and one use-case addressing Maintenance 4.0 which are: Course 1, emphasizing Advanced Maintenance Strategies, and Course 2, dedicated to Integrated Maintenance Planning. These courses encompass various use cases involving real-time communication, data acquisition, and storage in Industry 4.0, machine learning applications for maintenance and KPI assessment, as well as dashboarding and data visualization.

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1. Introduction

This document is developed as part of the ENHANCE project in pilot 1 of maintenance 4.0. The content describes all developed courses and related activities for the topic Maintenance 4.0, providing a comprehensive overview of the curriculum designed to enhance maintenance in the era of Industry 4.0. It includes detailed course descriptions, a short objective of each developed activity, some screens per activity, the link in the public platform, and its Syllabus.

1.1. Purpose of the document

This document presents the set of maintenance training activities developed and structured under two courses and one use-case. For each training activity, an overview of the content is introduced and the direct link to activity slides on the Learning Platform (https://lel.eplus-enhance.eu/) was provided. According to the ENHANCE learning platform, each activity was organised in a set of training tasks to increase the understanding of the proposed concepts and facilitate the acquisition of new maintenance skills.

1.2. Applicability

This document will be used by Moroccan and Tunisian partners to improve their curricula addressing maintenance 4.0 topics.

1.3. Definitions

N/A

1.4. Structure of the document

This document is organized in 9 sections:

- Section 1: introduction
- Section 2: ENHANCE project overview
- Section 3: Course 1: Advanced Maintenance Strategies
- Section 4: Course 2: integrated maintenance planning
- Section 5: Use case 1
- Section 6: References

1.5. List of acronyms

- **DIK**: Data, Information, and Knowledge
- **FMEA**: Fault Modes and Effects Analysis
- **FMECA**: Fault Modes Effects and Criticality Analysis
- **FTA**: Fault Tree Analysis
- **IoT:** Internet of Things
- **IIoT**: Industrial Internet of Things
- **MPQ:** Maintenance, Production, and Quality Engineering
- **ML:** Machine Learning
- **RUL**: Remaining Useful Life
- **SN**: Sensor Network
- **WSN**: Wireless sensor network
- **XR**: Xtended Reality

2. 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, being conducted in the period January 2021 until January 2024. It engages 7 partners from 5 countries with a total budget of 779k€. Further information can be found at http://eplus-enhance.eu/. Figure 1 gives an overview of the ENHANCE project organization.

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 workshop 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. The overall organization of the project can be seen in Figure 1.

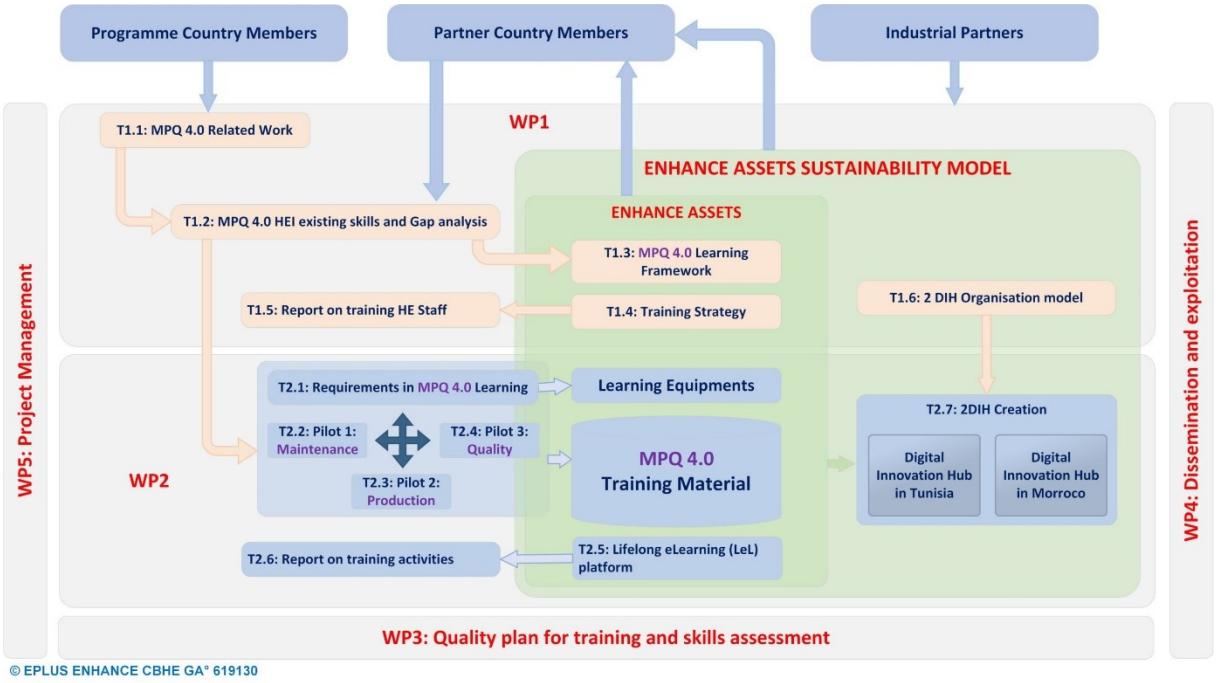

Figure 1. ENHANCE project organization.

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) with confirmed MPQ 4.0 competencies, training materials, collaborative research projects, full operational Digital Innovation Hubs (DIHs), 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 with contributions from the existing training programmes and consolidated through experimentations within three

industrial pilots. The new material will be used to train the mentors and the students in the 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.

3. Course 1: Advanced Maintenance Strategies

3.1. Course objectives

This course on Advanced Maintenance Strategies aims to prepare participants with a comprehensive understanding of Smart Maintenance 4.0 and its integration within Industry 4.0 contexts. It focuses on enabling the design and implementation of efficient sensor networks for predictive maintenance while emphasizing the integration of energy management strategies to optimize the usage and to minimize downtimes. Additionally, the course highlights sustainability-driven approaches, emphasizing eco-friendly practices, resource optimization, and asset longevity. Practical application through case studies and simulations enhances skills in data-driven decision-making, enabling participants to optimize maintenance strategies, enhance asset performance, and promote sustainable industry practices within modern manufacturing environments.

3.2. Presentation of the list of activities

3.2.1. Act 1.1: Use cases of eXtended Reality (XR) in Smart Maintenance 4.0 contexts

This activity demonstrates how the manufacturing industry can take advantage of emerging extended reality technologies (XR). Maintenance is one field among others where these technologies can provide assistance to the worker, the know-how of a remote expert, virtual training environment with zero risk and all the useful information at the right time and in the right place in front of his eyes to carry out his task (see figure 2)

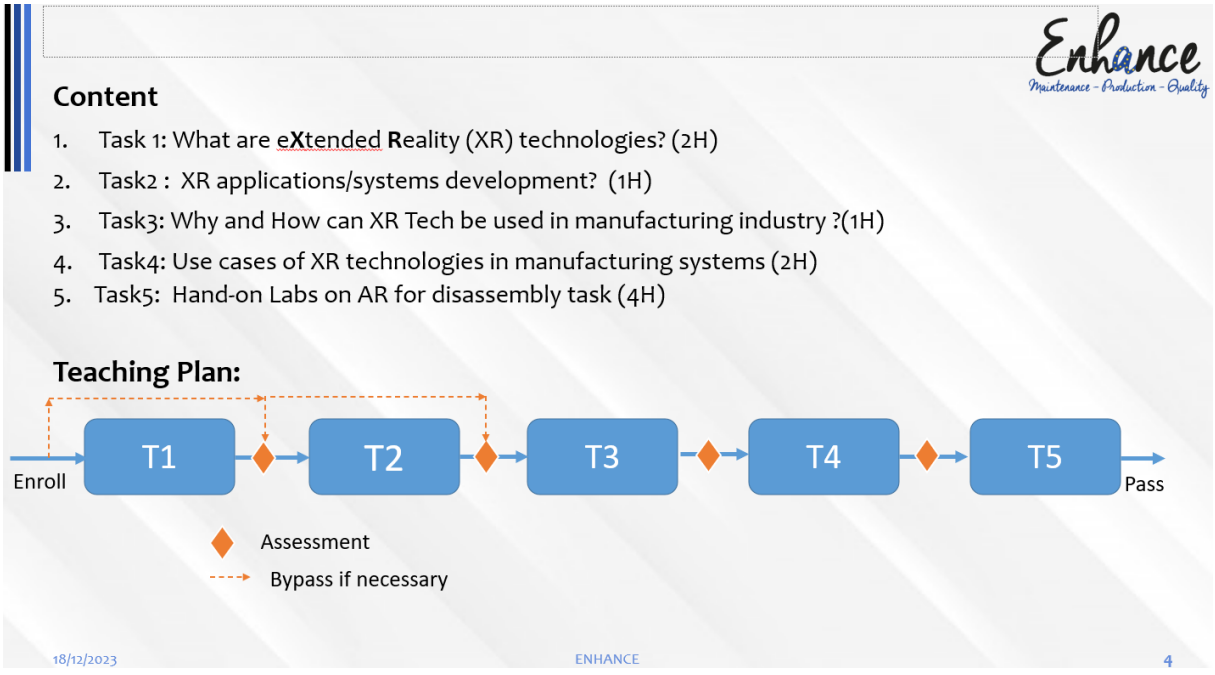

Figure 2: Print Screen of activity 1.1

More information may be found at the learning platform at URL https://lel.eplus-enhance.eu/course/view.php?id=2 (access credentials are available for EC reviewers)

The content is organized according to the following syllabus:

Enhance Maintenance - Production - Quality	**Learning Activity Syllabus**						Co-funded by the Erasmus+ Programme of the European Union
ENHANCE Domain	Maintenance						
Skill Set	Advanced Maintenance strategies						
Activity Title	Use cases of eXtended Reality (XR) in Smart Maintenance 4.0 contexts						
Activity Acronym	Act_1.1						
Activity Description	This activity demonstrates how the manufacturing industry can take advantage of emerging extended reality technologies (XR). Maintenance is one field among others where these technologies can provide assistance to the worker, the know-how of a remote expert, virtual training environment with zero risk and all the useful information at the right time and in the right place in front of his eyes to carry out his task.						
Keywords	Extended reality XR	augmented reality AR	mixed reality MR	virtual reality VR	Worker guidance/assistance system	Remote assistance	

Teaching task related to I4.0	**Topics**	**Teaching Plan**				**Learning Path**		
	Hard Skill	**Delivery Method (gamification, case study, simulation...)**		**Teaching Material**	**Duration (Hrs)**	**Soft Skill**	**Assesment**	**If FAIL goes to**	**If PASS goes to**
Task 1: What are eXtended Reality (XR) technologies?	Be able to: * Define what is an AR/VR/MR user experience? * Describe the architecture of XR system, its subsystems and their functions. * Enumrate the different forms of AR/VR, the needed equipement and their main features. * Make the right choice of the suitable form of XR technologies for a specific context	lecture	Illustration by videos	power point slides White papers	2H	.Critical thinking . Presentation	MCQ	Act 1.1-UCXRSM_Task1	Act 1.1-UCXRSM_Task2
Task 2: XR applications/systems development	Be able to: * Enumarate the main skills needed to develop XR applications and choose the suitable equipement. * Describe the typical workflow for XR app devlopement * Cite the most used tool chains, framworks and plateform for authoring XR content	lecture		power point slides	1H	.Critical thinking . Presentation	MCQ	Act 1.1-UCXRSM_Task2	Act 1.1-UCXRSM_Task3
Task3: Why and How can XR Tech be used in manufacturing industry ?	Be able to: * Enumarate the main fileds in manufacturing systems where XR tech is used with a real added value.	lecture	discussion	power point slides Report on AR startups	1H	.Critical thinking . Presentation	MCQ	Act 1.1-UCXRSM_Task3	Act 1.1-UCXRSM_Task4
Task 4: Use cases of XR technologies in manufacturing systems	Be able to: * Explore the possibilities of using XR in manufacturing industry that bring real added value * propose suitable solutions * draw up specifications for an XR system to be developped by third party or in house * anticpate issues related to limitations of XR technologies	lecture	Illustration by videos	power point slides	2H	.Critical thinking . Presentation	MCQ+Study of Scientific research articles with presentation	Act 1.1-UCXRSM_Task4	Act 1.1-UCXRSM_Task5
Task5 : Hand-on Labs on AR for assisted disassembly task	Be able to: * develop an AR app that implement the two fundamental concept of tracking and registration without need of hard programming. * develop a worker guidnace system using AR that overlays an interactive sequence of textual working instructiions, or audio instruction and a 3D animation illustration * develop an AR app for inspection of the internal temperature and humidity of warehouse of Ficshertechnic Smart factory.	Hands on Labs		Tutorial Online documentation of Openspace3D Youtube channel	6H	Team worker Critical thinking Presentation Problem solving	Project	Act 1.1-UCXRSM_Task4 or Act 1.1-UCXRSM_Task5	

Meta Skills							
Module Outcomes	Participants will be able to: * Define and describe the different form of XR technologies.		Participants will be able to * Enumarate the main succeful use cases of XR technologies in manufacturing industry and particularily in maintenance field.		Participants will be able to *explore possibilities to propose succesful use of XR systems in manufacturing industry and draw up specifications for an XR system to develop that will be suitable for a considered context.		Participants will be able to *anticipate some limitation of XR technologies to avoid using it in non suitable or without bring any added value for the considered context.
Target Group *(students, workers...)*	Master students	SME personnels	Teachers/trainers	Researchers/ Phd Student			
Assessment Method	MCQ and Project report						
Teaching Material							
Equipment	tablet	smartphone	PC+webcam	Microcontroller ESP82266	Smart factory Fischertechnic	Headset Oculus	
Multimedia	videos						
Content URL	Video URL						
Class requirements *(equipement that participants should bring)*	Personnel computer						
Prerequisites *(previous modules that student should attend)*	IOT						
Total duration *(Hrs)*	12						

3.2.2. Act 1.2: Sensor Network Design in Smart Maintenance 4.0 Contexts

This activity is addressing the design an efficient sensor network within Smart Maintenance 4.0 frameworks aimed at enabling real-time asset monitoring, predictive maintenance, and data-driven decision-making to enhance operational reliability and minimize downtime in industrial settings. The activity deals with the fundamentals of designing Sensor networks for I4.0 applications (example of smart maintenance). The following figure 3 illustrates this activity.

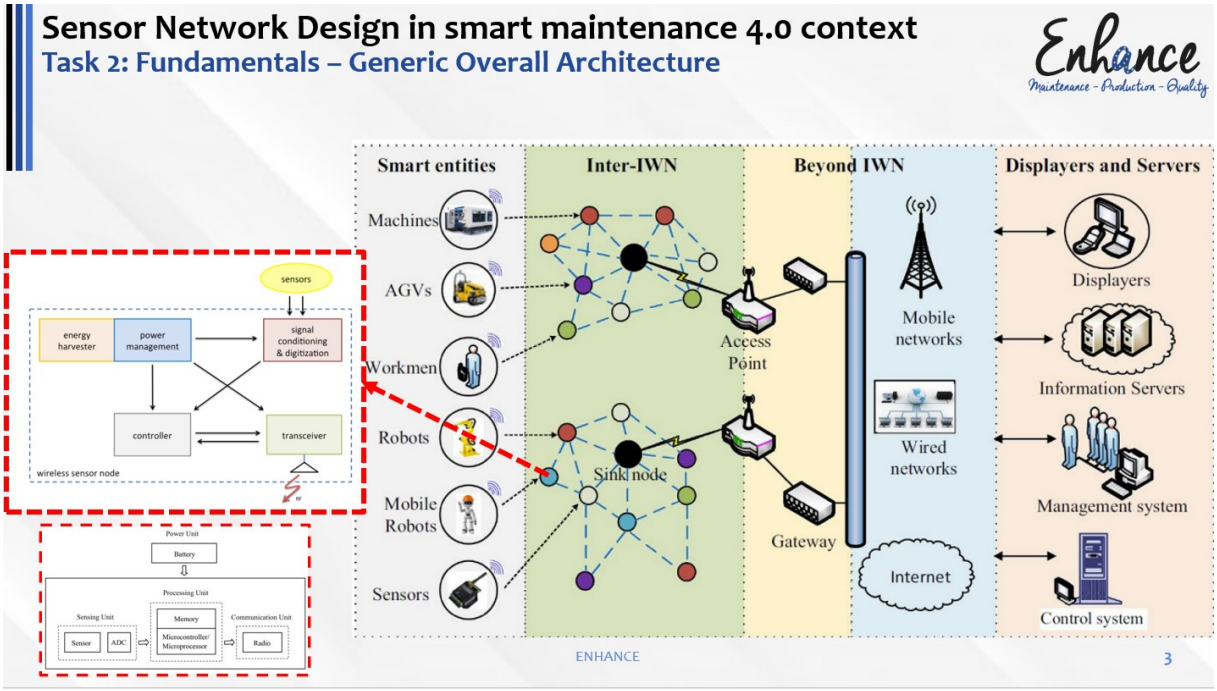

Figure 3 : Print Screen of activity 1.2

More information may be found at the learning platform at URL https://lel.eplus-enhance.eu/course/view.php?id=4 (access credentials are available for EC reviewers)

The content is organized according to the following syllabus:

Enhance – Maintenance – Production – Quality	**Learning Activity Syllabus**						Co-funded by the Erasmus+ Programme of the European Union
ENHANCE Domain	Maintenance						
Skill Set	Advanced Maintenance strategies						
Activity Title	**Sensor Network Design in Smart Maintenance 4.0 contexts**						
Activity Acronym	Act_1.2						
	This activity is addressing the design an efficient sensor network within Smart Maintenance 4.0 frameworks aimed at enabling real-time asset monitoring, predictive maintenance, and data-driven decision-making to enhance operational reliability and minimize downtime in industrial settings. The activity deals with the fundamentals of designing Sensor networks for I4.0 applications (example of smart maintenance).						
Keywords	Sensor/Actuator	Requirement	Design principles	Network	Communication		

Teaching task related to I4.0	**Topics**		**Teaching Plan**					**Learning Path**		
	Hard Skill		**Delivery Method (gamification, case study, simulation...)**		**Teaching Material**	**Duration (Hrs)**	**Soft Skill**	**Assesment**	**If FAIL goes to**	**If PASS goes to**
Task1	Challenges Needs for Data Handling, Analysis and Decision-making capabilities Importance of SN in Maintenance Application of WSN		Lecture	Presentation Discussion	ppt slides	2	Problem Solving, Critical thinking, Team working, Presentation, Infographic Communication,	Quizz	Task 1 (repeat until done)	Task 2
Task2	Understanding the relevant terms for SN Architecture design examples DIK Pyramid Sensor types and cabability ies		Lecture	Presentation Discussion	ppt slides Videos	2	Problem Solving, Critical thinking, Team working, Presentation, Infographic Communication,	Quizz	Task 2 (repeat until done)	Task 3
Task3	Wireless Sensor technologies and topologies for the design of WSNs Energy Harvesting: needs and techniques		Lecture	Presentation Discussion	ppt slides	2	Problem Solving, Critical thinking, Team working, Presentation, Infographic Communication,	Quizz	Task 3 (repeat until done)	Task 4
Task4	Requirements Engineering Design Considerations/issues		Lecture	Presentation Discussion	ppt slides	2	Problem Solving, Critical thinking, Team working, Presentation, Infographic Communication,	Quizz	Task 4 (repeat until done)	Task 5
Task5	Application of SN in a industrial application		Lecture	Presentation Discussion	ppt slides	2	Problem Solving, Critical thinking, Team working, Presentation, Infographic Communication,	prototyping	refienement	Done

Meta Skills	Effective storytelling						
Module Outcomes	Participants will be able to design, prototype and deploy SN in different industrial apllications						
Target Group *(students, workers...)*	Master students	SME personnels					
Assessment Method	Project report, Project presentation, Assessment rubric for teamwork, Quizzes						
Teaching Material							
Equipment	Fischertechnik	Sensors/actuators	embedded systems for data handling				
Multimedia							
Content URL							
Class requirements *(equipement that participants should bring)*	Laptopos/Notebooks/Deskt ops						
Prerequisites *(previous modules that student should attend)*							
Total duration *(Hrs)*	10						

3.2.3. Act 1.3: Failure Modes, Effects & Criticality Analysis (FMECA) in Smart Maintenance 4.0 context

Failure Mode and Effects Analysis plays a critical role in identifying system bottlenecks and mitigating the adverse consequences within high-risk industries. This activity introduces the main concepts related to maintenance in particular to FMEA. It also deals with the different types of FMEAs, current drawbacks, and limitations of classical-FMEA theories. FMEA models that performs the uncertainty quantification and machine learning techniques, MCDM methods, and other complementary failure analysis approaches are introduced. Smart-FMEA platform in modern industries and its improvements in the context of Industry 4.0 are discussed (see figure 4)

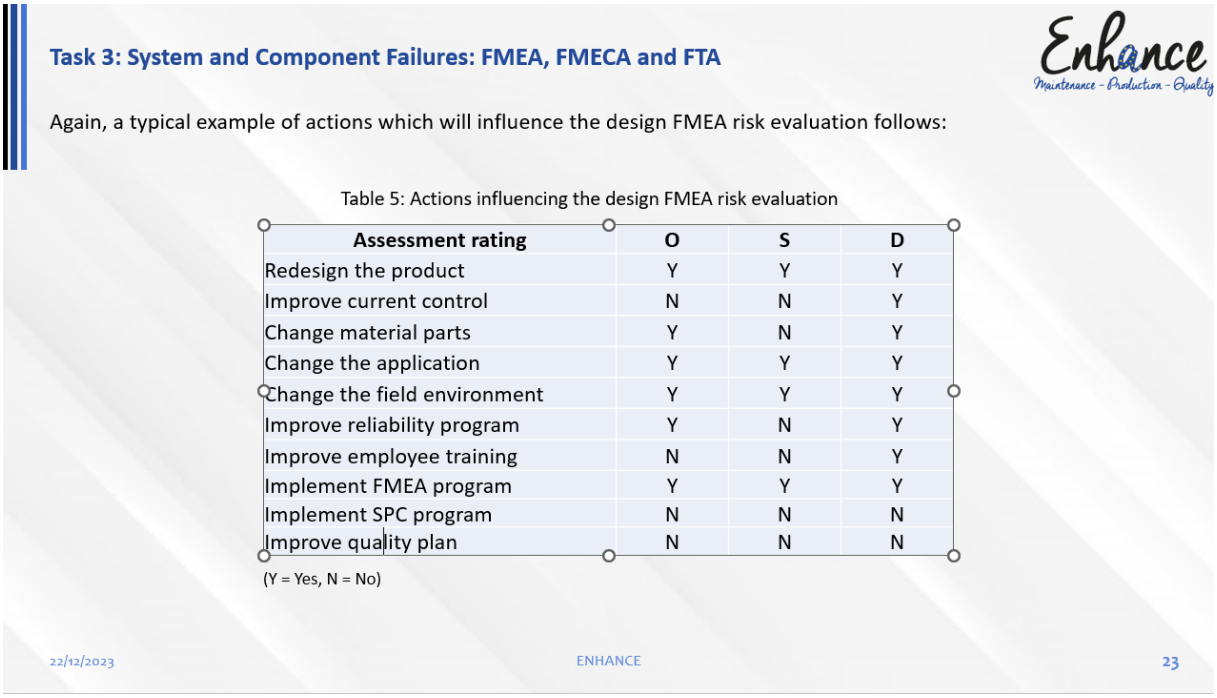

Figure 4 : Print Screen of activity 1.3

More information may be found at the learning platform at URL https://lel.eplus-enhance.eu/course/view.php?id=3 (access credentials are available for EC reviewers)

The content is organized according to the following syllabus:

Enhance	**Learning Activity Syllabus**						Co-funded by the Erasmus+ Programme of the European Union
ENHANCE Domain	Maintenance						
Skill Set	Advanced Maintenance strategies						
Activity Title	Failure Mode Analysis in Industry 4.0						
Activity Acronym	Act_1.3						
Activity Description	Failure Mode and Effects Analysis plays a critical role in identifying system bottlenecks and mitigating the adverse consequences within high-risk industries. This activity introduces the main concepts related to maintenance in particular to FMEA. It also deals with the different types of FMEAs, current drawbacks, and limitations of classical-FMEA theories. FMEA models that perform the uncertainty quantification and machine learning techniques, MCDM methods, and other complementary failure analysis approaches are introduced. Smart-FMEA platform in modern industries and its improvements in the context of Industry 4.0 are discussed.						
Keywords	Failure mode and effect analysis	Reliability	Maintenance	Risk management	Industry 4.0	Decision making	

Teaching task related to I4.0	**Topics**	**Teaching Plan**				**Learning Path**		
	Hard Skill	**Delivery Method (gamification, case study, simulation...)**		**Teaching Material**	**Duration (Hrs)**	**Soft Skill**	**Assesment**	**If FAIL goes to**	**If PASS goes to**
Task 1: An overview of Maintenance, Classification and Performance of Engineered Objects	Define maintenance and explain its importance from a strategic business perspective; provide a classification of engineered objects; describe the factors that affect performance degradation; describe the main categories of maintenance costs; explain that there are maintenance decision-making problems at the strategic, tactical, and operational levels	Lecture		ppt slides	1	Critical thinking	MCQ	Iterate Task 1	Task2
Task 2: Functions, Failures, Faults, Failure Modes, Degradation and Reliability Concept	Describe an engineered object as a multi-level system; define system functions and describe their classification, define system failure and faults and provide a proper classification of failure, define system reliability; define the failure rate function and provide its interpretation	Lecture		ppt slides	1	Critical thinking	MCQ	Iterate Task 2	Task3
Task 3: System and Component Failures: FMEA, FMECA and FTA	Define system failure causes and describe their classification; describe system degradation leading to failure; describe different methods for the linking of component failures to system failure; conduct FMEA, construct FTA, and derive structure functions for simple systems	Lecture	Illustration by videos	ppt slides Equation sheet FMEA Test FMEA template	2	Problem Solving Critical thinking	MCQ	Iterate Task 3	Task4
Task 4: FMEA in Product Development in Industry 4.0	Understand how I4.0 technologies can help implementing and improving FMEA (automated root cause analysis, automatically identify, classify and prioritize, continuous updates from data sources, etc.); define FMEA as a management tool instead of a project	Lecture		ppt slides	1	Critical thinking	MCQ	Iterate Task 4	Task 5
Task 5: FMEA and Machine Learning : application in agricultural machinery industry	Understand how to use a specific AI approach to implement and enhance FMEA in industry	Lecture		ppt slides	1	Critical thinking	MCQ	Iterate Task 5	Go to subsequent activity

Module Outcomes	Participants will be able to describe the main categories of maintenance costs; explain that there are maintenance decision-making problems at the strategic, tactical, and operational levels		Participants will be able to define system failure and faults and provide a proper classification of failure, define system reliability; define the failure rate function and provide its interpretation		Participants will be able to understand how I4.0 technologies can help implementing and improving FMEA		
Target Group *(students, workers...)*	Master students	SME personnels	Teachers/trainers	Researchers/ Phd Student			
Assessment Method	Project report, Project presentation, Assessment rubric for teamwork						
Teaching Material							
Equipment	Computer for Task 3	Excel or Statistcal Processing Software					
Multimedia	Lecture notes						
Content URL	No need						
Class requirements *(equipement that participants should bring)*	No need						
Prerequisites *(previous modules that student should attend)*	Basics of maintenance strategies, Reliability and maintenance	Problem solving tools, data collection and analysis (Ishikawa diagrams, Pareto charts or Pareto diagrams, 5W and 2H, Statistical process control, Scatter plots, Design of experiments, Histograms, Flowcharts or process maps,...)	Machine Learning and AI				
Total duration *(Hrs)*	6 (Content to be adapted, sections to be selected depending on participants)						

3.2.4. Act 1.4: Contributions of Smart Maintenance 4.0 to Energy Management & Energy Efficiency of Industry 4.0 Assets

The objective of this activity is the leverage Smart Maintenance 4.0 to optimize energy usage in Industry 4.0 by deploying predictive maintenance, real-time monitoring, and data analytics. This approach aims to reduce downtime, enhance asset efficiency, and ensure sustainable operations while minimizing energy consumption (see figure 5)

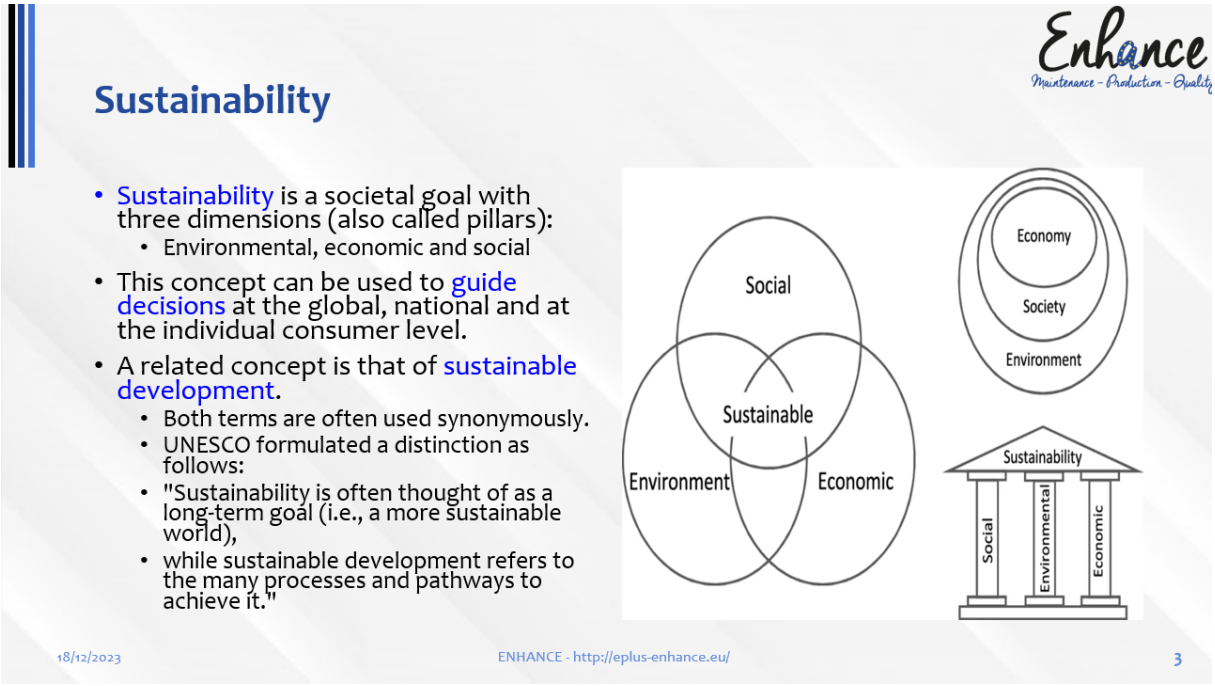

Figure 5 : Print Screen of activity 1.4

More information may be found at the learning platform at URL https://lel.eplus-enhance.eu/course/view.php?id=42 (access credentials are available for EC reviewers)

The content is organized according to the following syllabus:

Enhance	**Learning Activity Syllabus**									
								Co-funded by the Erasmus+ Programme of the European Union		
ENHANCE Domain	Maintenance									
Skill Set	D2.2 - Maintenance Pilot - Course 1 - Advanced Maintenance strategies									
Activity Title	Contributions of Smart Maintenance 4.0 to Energy Management & Energy Efficiency of Industry 4.0 Assets									
Activity Acronym	Act_1.4									
Activity Description	The objective of this activity is the leverage Smart Maintenance 4.0 to optimize energy usage in Industry 4.0 by deploying predictive maintenance, real-time monitoring, and data analytics. This approach aims to reduce downtime, enhance asset efficiency, and ensure sustainable operations while minimizing energy consumption.									
Keywords	Smat Maintenance 4.0	Energy Management	Energy Efficiency	Asset Management						
Teaching task related to I4.0	**Topics**		**Teaching Plan**					**Learning Path**		
	Hard Skill		**Delivery Method (gamification, case study, simulation...)**		**Teaching Material**	**Duration (Hrs)**	**Soft Skill**	**Assesment**	**If FAIL goes to**	**If PASS goes to**
Task 1	Introduction Sustainability Energy sustainability Energy management Energy efficiency Standardization of Energy Efficiency in I4.0		.Presentation .Infographic communication		ppt slides	2	.Problem Solving .Critical thinking .Team working	Quizz	Task 1 (repeat until done)	Task 2
Task 2	Digital transformation in the resource and energy sectors		.Presentation .Infographic communication		ppt slides	2	.Problem Solving .Critical thinking .Team working	Quizz	Task 2 (repeat until done)	Task 3
Task 3	Intelligence in the energy sector Intelligent/Smart Energy Management Systems Digital Twins in the energy sector		.Presentation .Infographic communication		ppt slides	2	.Problem Solving .Critical thinking .Team working	Quizz	Task 3 (repeat until done)	Task 4
Task 4	Energy, Manufacturing & Maintenance Energy Efficient Manufacturing Energy Based Maintenance		.Presentation .Infographic communication		ppt slides	2	.Problem Solving .Critical thinking .Team working	Quizz	Task 4 (repeat until done)	Task 5
Task 5	Tutorials Energy efficiency in electrical utilities Performance evaluation of electric motors and variable speed drives		.Presentation .Infographic communication		ppt slides	4	.Problem Solving .Critical thinking .Team working	Quizz	Task 5 (repeat until done)	Done
Meta Skills	NA									
Module Outcomes	Participants will be able to define and identify contributions of Smart Maintenance 4.0 to Energy Management & Energy Efficiency of Industry 4.0 Assets									
Target Group *(students, workers...)*	Master students	SME personnel								
Assessment Method	Quizzes, Project report, Project presentation, Assessment of teamwork									
Teaching Material										
Equipment	Technivib workbench									
Multimedia										
Content URL										
Class requirements *(equipement that participants should bring)*	Laptop/Desktop									
Prerequisites *(previous modules that student should attend)*	Act U.1.2									
Total duration *(Hrs)*	12									

3.2.5. Act 1.5: Sustainability Driven Smart Maintenance 4.0

The activity aims to strength the knowledge of participants in the field of sustainable maintenance. It focuses mainly on industry 4.0 technologies required to achieve sustainability driven goals for maintenance (see figure 6)

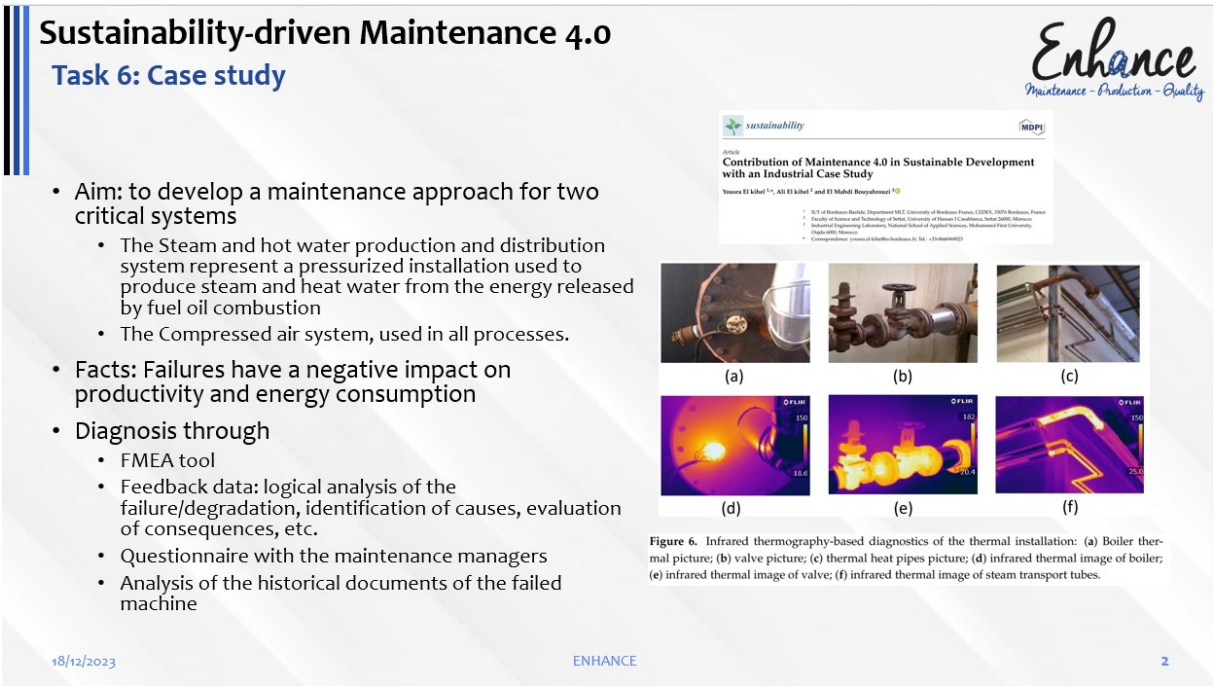

Figure 6 : Print Screen of activity 1.5

More information may be found at the learning platform at URL https://lel.eplus-enhance.eu/course/view.php?id=21 (access credentials are available for EC reviewers)

The content is organized according to the following syllabus:

Enhance	**Learning Activity Syllabus**						Co-funded by the Erasmus+ Programme of the European Union
ENHANCE Domain	Maintenance						
Skill Set	Advanced Maintenance strategies						
Activity Title	**Sustainability-Driven Smart Maintenance 4.0**						
Activity Acronym	Act_1.5						
Activity Description	The activity aims to strength the knowledge of participants in the field of sustainable maintenance. It focuses mainly on industry 4.0 technologies required to achieve sustainability driven golas for maintenance.						
Keywords	SDGs	Sustaibnability	Maintenance	Industry 4.0 technologies	effects/benefits		

Teaching task related to I4.0	**Topics**	**Teaching Plan**				**Learning Path**		
	Hard Skill	**Delivery Method (gamification, case study, simulation...)**		**Teaching Material**	**Duration (Hrs)**	**Soft Skill**	**Assesment**	**If FAIL goes to**	**If PASS goes to**
Task 1: Introduction	Maintenance strategies evolution, Definition of Sustainability	Lecture	Presentation Discussion	ppt slides	2	Problem Solving, Critical thinking, Team working, Presentation, Infographic Communication,	Quizz	Task 1 (repeat until done)	Task 2
Task 2: Sustainability Development	launched	Lecture	Presentation Discussion	ppt slides	4	Problem Solving, Critical thinking, Team working, Presentation, Infographic Communication,	Quizz	Task 2 (repeat until done)	Task 3
Task 3: I4.0 technologies integration in maintenance processes	potential Industry 4.0 technologies for Maintenance processes	Lecture	Presentation Discussion	ppt slides	4	Problem Solving, Critical thinking, Team working, Presentation, Infographic Communication,	Quizz	Task 3 (repeat until done)	Task 4
Task 4: Effects of I4.0 on Sustainability-driven Maintenance	Positive and negative effects on maintenance	Lecture	Presentation Discussion	ppt slides	6	Problem Solving, Critical thinking, Team working, Presentation, Infographic Communication,	Quizz	Task 4 (repeat until done)	Task 5
Task 5: Potential benefits	Potential benefits of Industry 4.0 technologies on differents sustainability dimensions	Lecture	Presentation Discussion	ppt slides	2	Problem Solving, Critical thinking, Team working, Presentation, Infographic Communication,	Quizz	Task 5 (repeat until done)	Task 6
Task 6: Case study	industrial scenariio: sustaibale maintenance strategy for Steam and hot water production and distribution system	case study	Presentation Discussion	ppt slides	6	Problem Solving, Team working, co creation, communication,	Quizz	Task 6 (repeat until done)	Done

Meta Skills	Effective storytelling						
Module Outcomes	Participants will enrich his knowledge about maintenance driven maintenance and understand which technolgies for which purposes could be adopted.						
Target Group *(students, workers...)*	Master students	SME personnels					
Assessment Method	Project report, Project presentation, Assessment rubric for teamwork, Quizzes						
Teaching Material							
Equipment	Simulation software	IIoT	Fischertechnik as application scenario				
Multimedia	Lecture notes	Role play scene setup					
Content URL	Video URL						
Class requirements *(equipement that participants should bring)*	Laptopos/Notebooks/Deskt ops						
Prerequisites *(previous modules that student should attend)*	Act 1.4	Act 2.2	Act 2.5				
Total duration *(Hrs)*	24						

4. Course 2: Integrated maintenance planning

4.1. Course objectives

This course on Integrated Maintenance Planning merges key elements including maintenance pilot implementation, scheduling methodologies, and the integration of Industry 4.0 technologies into Total Productive Maintenance (TPM). It focuses on enabling participants to forecast and minimize downtime through optimal or near-optimal maintenance planning while emphasizing the practical application of these concepts in real-world scenarios. By intertwining maintenance planning, scheduling strategies, and Industry 4.0 advancements, the course aims to equip individuals with comprehensive skills to streamline maintenance processes, enhance asset performance, and maximize productivity within industrial settings.

4.2. Presentation of the list of activities

4.2.1. Act 2.1: Data-Driven Reliability for Smart Maintenance 4.0

This activity is addressing the development and implementation of data-driven reliability strategies within Smart Maintenance 4.0 frameworks. Through the employment of advanced analytics and real-time data utilization to enhance asset reliability, enable predictive maintenance, and optimize operational efficiency, fostering sustainable and reliable industrial processes (see figure 7)

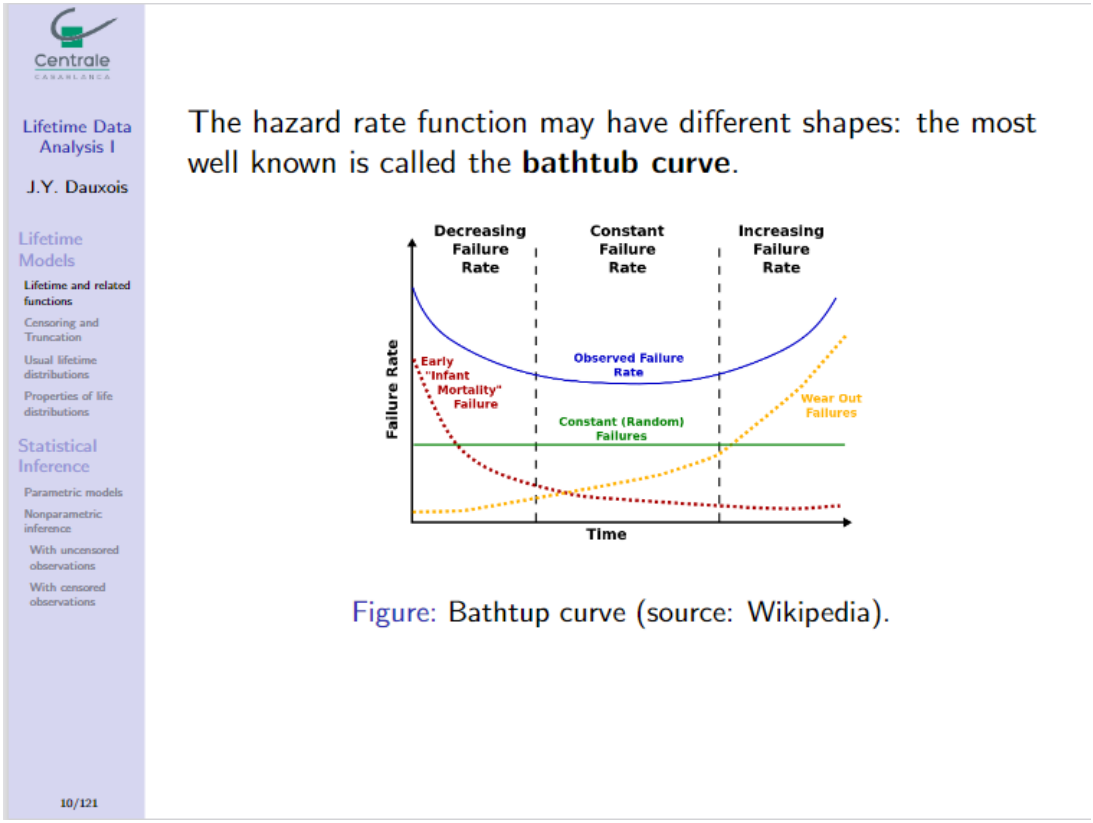

Figure 7 : Print Screen of activity 2.1

More information may be found at the learning platform at URL https://lel.eplus-enhance.eu/course/view.php?id=10 (access credentials are available for EC reviewers)

The content is organized according to the following syllabus:

Enhance	**Learning Activity Syllabus**										Co-funded by the Erasmus+ Programme of the European Union
ENHANCE Domain	Maintenance										
Skill Set	D2.2 - Maintenance Pilot - Course 2 - Integrated maintenance planning										
Activity Title	Data-Driven Reliability for Smart Maintenance 4.0										
Activity Acronym	Act_2.1										
Activity Description	This activity is addressing the development and implementation of data-driven reliability strategies within Smart Maintenance 4.0 frameworks. Through the employment of advanced analytics and real-time data utilization to enhance asset reliability, enable predictive maintenance, and optimize operational efficiency, fostering sustainable and reliable industrial processes.										
Keywords	Smart Maintenance	Data-Driven Reliability									

Teaching task related to I4.0	**Topics**		**Teaching Plan**				**Learning Path**		
	Hard Skill		**Delivery Method (gamification, case study, simulation...)**	**Teaching Material**	**Duration (Hrs)**	**Soft Skill**	**Assesment**	**If FAIL goes to**	**If PASS goes to**
Task 1	Lifetime models Statistical inference		.Presentation .Infographic communication	ppt slides	7	.Problem Solving .Critical thinking .Team working	Quizz	Task 1 (repeat until done)	Task 2
Task 2	Statistical inference continued Regression models		.Presentation .Infographic communication	ppt slides	7	.Problem Solving .Critical thinking .Team working	Quizz	Task 2 (repeat until done)	Task 3
Task 3	Counting processes for repairable systems Homogeneous Poisson Processes		.Presentation .Infographic communication	ppt slides	6	.Problem Solving .Critical thinking .Team working	Quizz	Task 3 (repeat until done)	Done

Meta Skills							
Module Outcomes	Participants will be able to define and identify concepts related to data-driven reliability for smart maintenance 4.0						
Target Group *(students, workers...)*	Master students	SME personnels					
Assessment Method	Project report, Project presentation, Assessment of teamwork						
Teaching Material							
Equipment	Technivib workbench						
Multimedia							
Content URL							
Class requirements *(equipement that participants should bring)*	Laptop/Desktop						
Prerequisites *(previous modules that student should attend)*	Act U.1.2	Act_U.1.3					
Total duration *(Hrs)*	20						

4.2.2. Act 2.2: Maintenance planning and scheduling

The objective of the activity is to refine maintenance planning and scheduling techniques by integrating Industry 4.0 methodologies for asset uptime optimization, streamlining workflows, and enhancing operational efficiency within industrial settings (see figure 8)

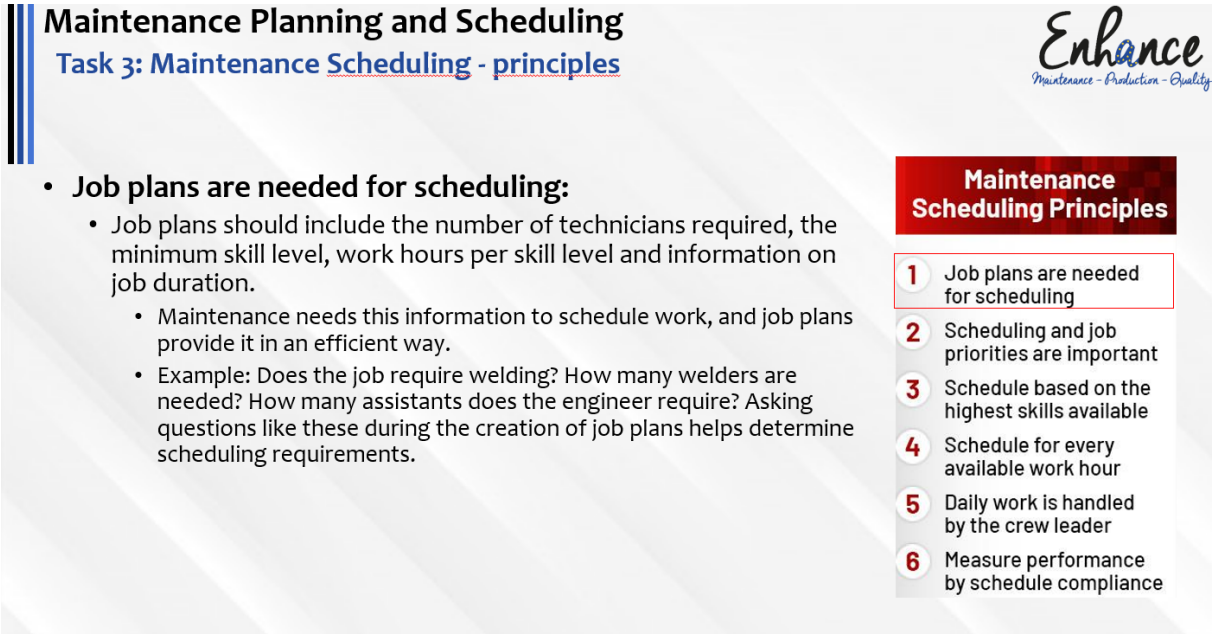

Figure 8 : Print Screen of activity 2.2

More information may be found at the learning platform at URL https://lel.eplus-enhance.eu/course/view.php?id=14 (access credentials are available for EC reviewers)

The content is organized according to the following syllabus:

Enhance	**Learning Activity Syllabus**						Co-funded by the Erasmus+ Programme of the European Union
ENHANCE Domain	Maintenance						
Skill Set	Integrated maintenance planning						
Activity Title	**Maintenance planning and scheduling**						
Activity Acronym	Act_2.2						
Activity Description	The objective of the activity is to refine maintenance planning and scheduling techniques by integrating Industry 4.0 methodologies for asset uptime optimization, streamlining workflows, and enhancing operational efficiency within industrial settings.						
Keywords	Maintenance planning and scheduling	Maintenance Scheduling	Maintenance strategies				

Teaching task related to I4.0	**Topics**		**Teaching Plan**					**Learning Path**		
	Hard Skill		**Delivery Method (gamification, case study, simulation...)**		**Teaching Material**	**Duration (Hrs)**	**Soft Skill**	**Assesment**	**If FAIL goes to**	**If PASS goes to**
Task1: Fundamentals	Understand the difference between the maintenance strategies		Lecture	Presentation Discussion	ppt slides	3	Problem Solving, Critical thinking, Team working, Presentation, Infographic Communication,	Quizz	Task 1 (repeat until done)	Task 2
Task2: Maintenance Planning	Understand all the steps and principles to be considered for planning maintenance activities		Lecture	Presentation Discussion	ppt slides Videos	3	Problem Solving, Critical thinking, Team working, Presentation, Infographic Communication,	Quizz	Task 2 (repeat until done)	Task 3
Task3: Maintenance Scheduling	Understand all the steps and principles to be considered for schedulingmaintenance activities		Lecture	Presentation Discussion	ppt slides Videos	3	Problem Solving, Critical thinking, Team working, Presentation, Infographic Communication,	Quizz	Task 3 (repeat until done)	Task 4
Task 4: Examples, practices and new terms	new terms, innovative approaches		Lecture	Presentation Discussion	ppt slides	2	Problem Solving, Critical thinking, Team working, Presentation, Infographic Communication,	Quizz	Task 4 (repeat until done)	Task 5

Meta Skills	Effective storytelling						
Module Outcomes	Participants will be familiar with the different typte of maintenance strategie		Participants will be able to differentiate between planning and scheduling				
Target Group *(students, workers...)*	Master students	SME personnels					
Assessment Method	Project report, Project presentation, Assessment rubric for teamwork, Quizzes						
Teaching Material							
Equipment	Simulation software	Fischertechnik					
Multimedia							
Content URL	Video URL						
Class requirements *(equipement that participants should bring)*	Laptopos/Notebooks/Desktops						
Prerequisites *(previous modules that student should attend)*	Act 1.5						
Total duration *(Hrs)*	11						

4.2.3. Act 2.3: Contributions of Industry 4.0 technologies to Total Productive Maintenance

The objective is the leverage of Industry 4.0 technologies to enhance Total Productive Maintenance (TPM). This approach will emphasize improved predictive analytics, real-time monitoring, and data-driven decision-making to optimize equipment reliability, minimize disruptions, and maximize overall productivity within manufacturing environments (see figure 9)

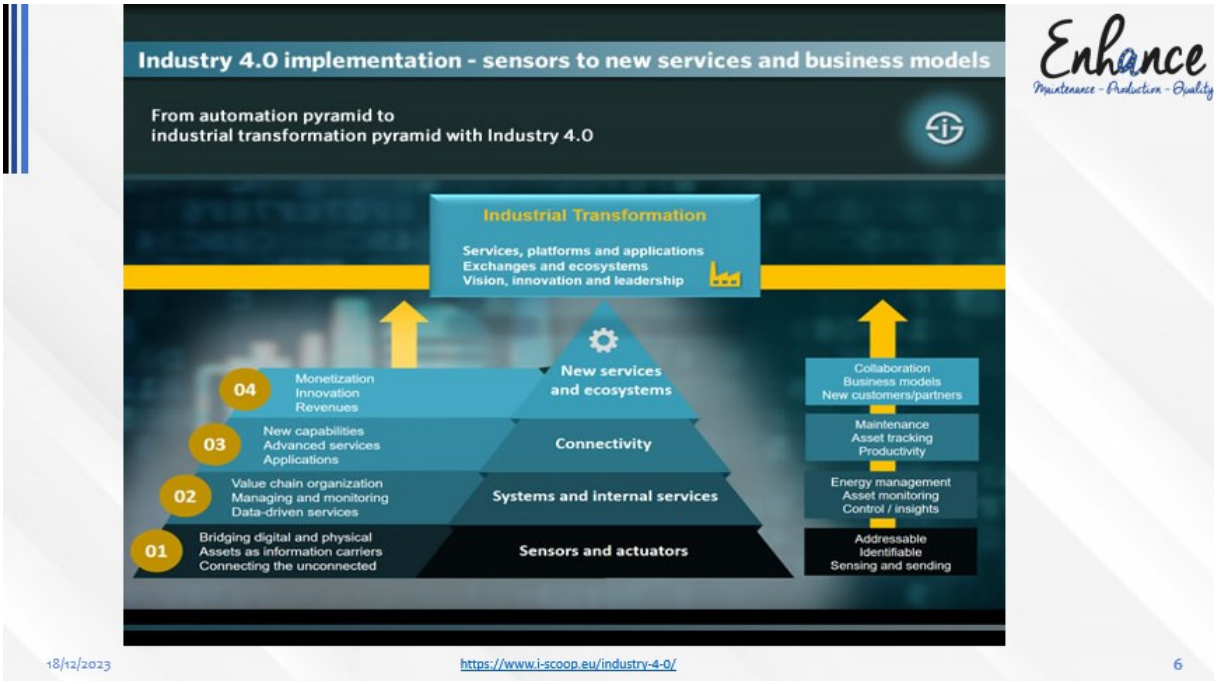

Figure 9 : Print Screen of activity 2.3

More information may be found at the learning platform at URL https://lel.eplus-enhance.eu/course/view.php?id=11 (access credentials are available for EC reviewers)

The content is organized according to the following syllabus:

Enhance	**Learning Activity Syllabus**	Co-funded by the Erasmus+ Programme of the European Union

ENHANCE Domain	Maintenance									
Skill Set	D2.2 - Maintenance Pilot - Course 2 - Integrated maintenance planning									
Activity Title	Contributions of Industry 4.0 technologies to Total Productive Maintenance									
Activity Acronym	Act_2.3									
Activity Description	The objective is the leverage of Industry 4.0 technologies to enhance Total Productive Maintenance (TPM). This approach will emphasize improved predictive analytics, real-time monitoring, and data-driven decision-making to optimize equipment reliability, minimize disruptions, and maximize overall productivity within manufacturing environments.									
Keywords	TPM 4.0									
Teaching task related to I4.0	**Topics**		**Teaching Plan**				**Learning Path**			
	Hard Skill		**Delivery Method (gamification, case study, simulation...)**		**Teaching Material**	**Duration (Hrs)**	**Soft Skill**	**Assesment**	**If FAIL goes to**	**If PASS goes to**
Task 1	Introduction Digital Transformation Maintenance & Lean		.Presentation .Infographic communication		ppt slides	2	.Problem Solving .Critical thinking .Team working	Quizz	Task 1 (repeat until done)	Task 2
Task 2	TPM: 8 Pillars Benefits of TPM		.Presentation .Infographic communication		ppt slides	2	.Problem Solving .Critical thinking .Team working	Quizz	Task 2 (repeat until done)	Task 3
Task 3	Indicators, OEE		.Presentation .Infographic communication		ppt slides	2	.Problem Solving .Critical thinking .Team working	Quizz	Task 3 (repeat until done)	Task 4
Task 4	TPM & I4.0 TPM Practices X I4.0 Technologies Maintenance processes X I4.0 Technologies Examples & Challenges		.Presentation .Infographic communication		ppt slides	2	.Problem Solving .Critical thinking .Team working	Quizz	Task 4 (repeat until done)	Task 5
Task 5	Case studies		.Presentation .Infographic communication		ppt slides	4	.Problem Solving .Critical thinking .Team working	Quizz	Task 5 (repeat until done)	Done
Meta Skills										
Module Outcomes	Participants will be able to define and identify Contributions of Industry 4.0 technologies to Total Productive Maintenance									
Target Group *(students, workers...)*	Master students	SME personnels								
Assessment Method	Project report, Project presentation, Assessment of teamwork									
Teaching Material										
Equipment	Technivib workbench									
Multimedia										
Content URL										
Class requirements *(equipement that participants should bring)*	Laptop/Desktop									
Prerequisites *(previous modules that student should attend)*	Act U.1.4									
Total duration *(Hrs)*	12									

4.2.4. Act 2.4: Downtime forecast and optimal maintenance planning

The goal of this activity is to provide an introduction into the large and important area of maintenance planning, provide an insight into different maintenance approaches, downtime cost assessment techniques and machine learning techniques to support the maintenance planning (see figure10)

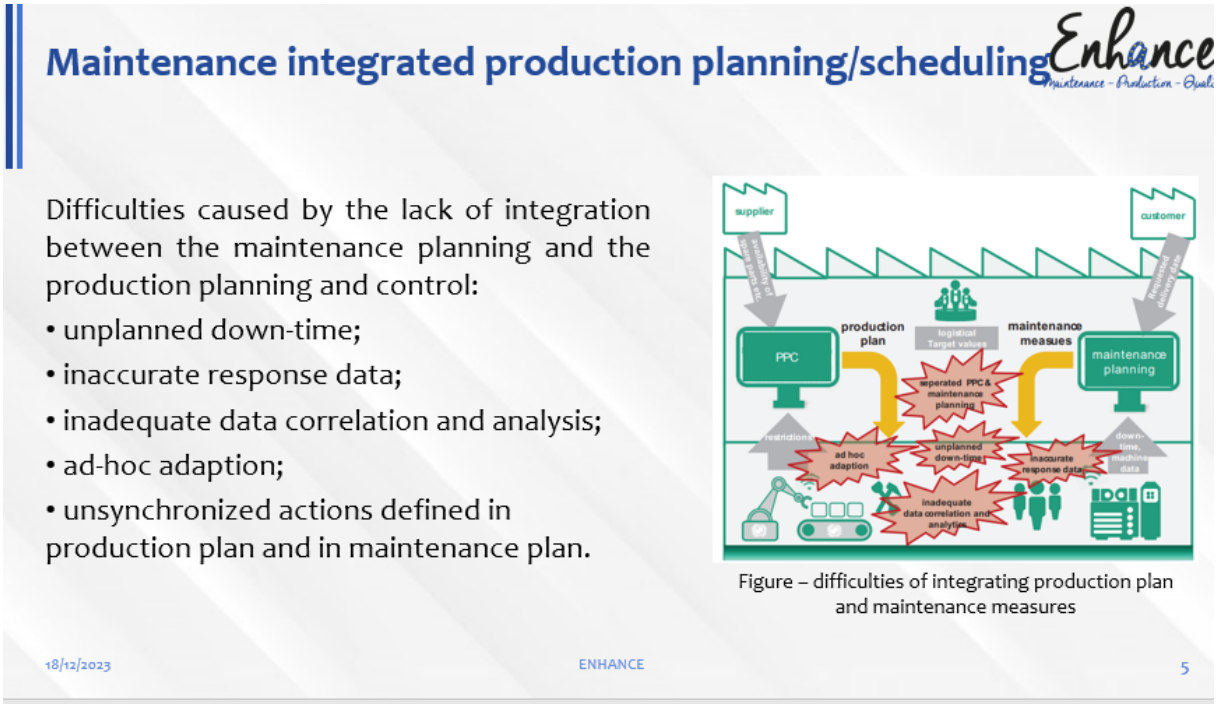

Figure – difficulties of integrating production plan and maintenance measures

Figure 10 : Print Screen of activity 2.4

More information may be found at the learning platform at URL https://lel.eplus-enhance.eu/course/view.php?id=7 (access credentials are available for EC reviewers)

The content is organized according to the following syllabus:

Enhance	**Learning Activity Syllabus**						Co-funded by the Erasmus+ Programme of the European Union
ENHANCE Domain	Maintenance						
Skill Set	Advanced Maintenance strategies						
Activity Title	Downtime forecast and optimal maintenance planning						
Activity Acronym	Act_2.4						
Activity Description	The goal of this course is to provide an introduction into the large and important area of maintenance planning, provide an insight into different maintenance approaches, downtime cost assessment techniques and machine learning techniques to support the maintenance planning.						
Keywords	Optimal maintenance	Downtine Forecast	Machine Learning				

Teaching task related to I4.0	**Topics**	**Teaching Plan**				**Learning Path**		
	Hard Skill	**Delivery Method (gamification, case study, simulation...)**		**Teaching Material**	**Duration (Hrs)**	**Soft Skill**	**Assesment**	**If FAIL goes to**	**If PASS goes to**
1. Fundamentals in Optimal Maintenance Theory	Understanding of basic Maintenance principles and downtime related costs, KPI for downtime impact assessment.	Lecture	Group Discussion	.ppt file	1h	.Critical thinking .Presentation .Infographic communication	Question 1	Task 3 (MDIS)	task 2 (SND)
2. Techniques and approaches for maintenance planning	How ML mdoels can contribute to Maintenance process optimization. Introduction of two main types of analytics approaches - the model-based and the data-based.	Lecture	Group Discussion	.ppt file	1h	.Critical thinking .Presentation .Infographic communication			
3. Internet-of-Things for Maintenance	How Industry 4.0 and IoT in particular supports the maintenance management. Demonstration of ML-based approaches form the literature.	Lecture	Group Discussion	.ppt file	1h	.Critical thinking .Presentation .Infographic communication			

Meta Skills							
Module Outcomes	Participants will get an understanding of Downtime Forecast and Maintenance Planning.		Participants will get the understanding of the tools, icluding ML used for Downtime Forecast and Maintenance Planing.				
Target Group *(students, workers...)*	Master students	SME personnels					
Assessment Method	Project report, Project presentation						
Teaching Material							
Equipment							
Multimedia	Lecture notes						
Content URL							
Class requirements *(equipement that participants should bring)*	Computer						
Prerequisites *(previous modules that student should attend)*	N/A						
Total duration *(Hrs)*	3						

4.2.5. Act 2.5: Industry 4.0 Asset & Maintenance Management Systems

This activity is addressing the implementation and integration of Industry 4.0 assets within maintenance management systems. This is achieved utilizing advanced technologies and data-driven approaches to optimize asset performance, streamline maintenance processes, and ensure efficient operations keeping in mind the alignment with the Industry 4.0 principles (see figure 11)

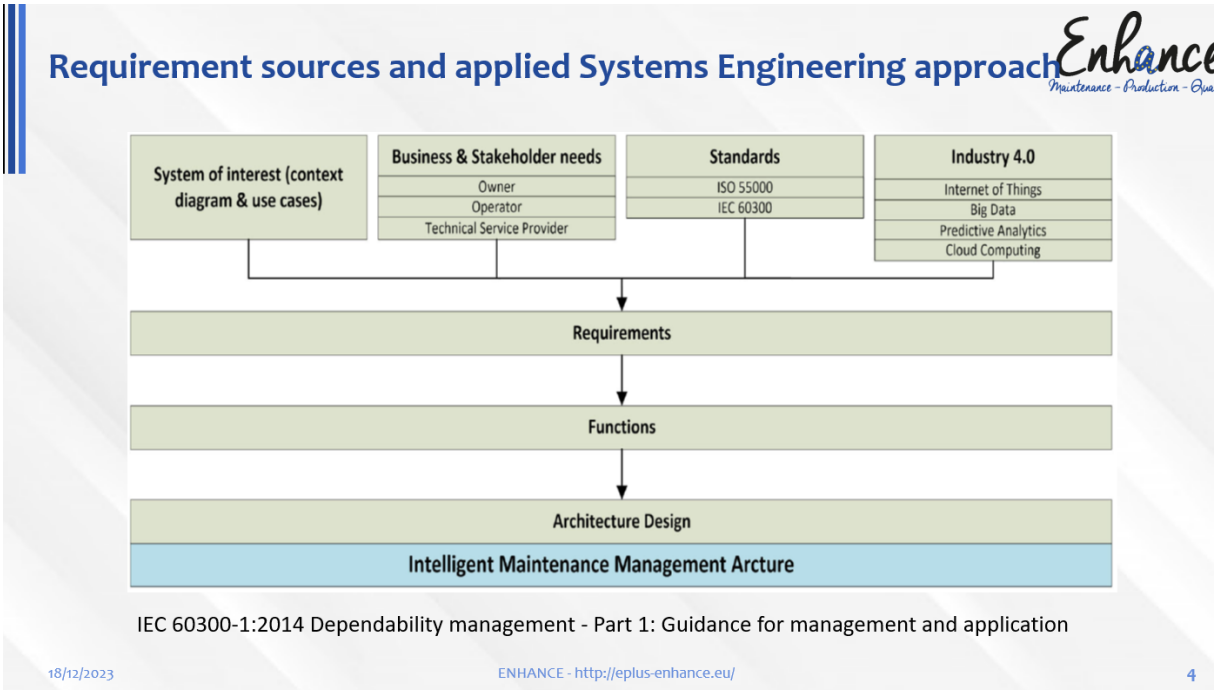

Figure 11 : Print Screen activity 2.5

More information may be found at the learning platform at URL https://lel.eplus-enhance.eu/course/view.php?id=19 (access credentials are available for EC reviewers)

The content is organized according to the following syllabus:

Learning Activity Syllabus

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

ENHANCE Domain	Maintenance						
Skill Set	D2.2 - Maintenance Pilot - Course 2 - Integrated maintenance planning						
Activity Title	Industry 4.0 Asset & Maintenance Management Systems						
Activity Acronym	Act_2.5						
Activity Description	This activity is addressing the implementation and integration of Industry 4.0 assets within maintenance management systems. This is achieved utilizing advanced technologies and data-driven approaches to optimize asset performance, streamline maintenance processes, and ensure efficient operations keeping in mind the alignment with the Industry 4.0 principles.						
Keywords	Maintenance Management	Asset Management					

Teaching task related to I4.0	**Topics**	**Teaching Plan**				**Learning Path**		
	Hard Skill	**Delivery Method (gamification, case study, simulation...)**	**Teaching Material**	**Duration (Hrs)**	**Soft Skill**	**Assesment**	**If FAIL goes to**	**If PASS goes to**
Task 1	Maintenance Engineering Maintenance Management Strategies	.Presentation .Infographic communication	ppt slides	4	.Problem Solving .Critical thinking .Team working	Quizz	Task 1 (repeat until done)	Task 2
Task 2	CMMS & EAM ISO 55000 Asset Management series of Standards Requirements for I4.0	.Presentation .Infographic communication	ppt slides	4	.Problem Solving .Critical thinking .Team working	Quizz	Task 2 (repeat until done)	Task 3
Task 3	Digital Maintenance Digital transformation : From traditional maintenance to M4.0	.Presentation .Infographic communication	ppt slides	4	.Problem Solving .Critical thinking .Team working	Quizz	Task 3 (repeat until done)	Task 4
Task 4	Architectures : OSA-CBM & RAMI 4.0 Technologies : Ontologies & Blockchains	.Presentation .Infographic communication	ppt slides	4	.Problem Solving .Critical thinking .Team working	Quizz	Task 4 (repeat until done)	Task 5
Task 5	Case study 1 Systems Engineering Case study 2 Knowledge-Based Systems Case study 3 Managing a project to implement CMMS/EAM	.Presentation .Infographic communication	ppt slides	4	.Problem Solving .Critical thinking .Team working	Quizz	Task 5 (repeat until done)	Done

Meta Skills							
Module Outcomes	Participants will be able to define and identify the benefits of Industry 4.0 technologies and practices to Asset & Maintenance Management Systems						
Target Group *(students, workers...)*	Master students	SME personnels					
Assessment Method	Project report, Project presentation, Assessment of teamwork						
Teaching Material							
Equipment	Technivib workbench						
Multimedia							
Content URL							
Class requirements *(equipement that participants should bring)*	Desktop/laptop						
Prerequisites *(previous modules that student should attend)*							
Total duration *(Hrs)*	20						

5. Use case 1

5.1. Course objectives

The objective of the Use Case for Maintenance 4.0 across domains is to demonstrate the versatile application of advanced maintenance strategies in diverse industrial sectors. It aims to showcase real-world scenarios where Maintenance 4.0 methodologies, including predictive maintenance, IoT integration, and data analytics for asset performance optimization, downtime reduction, and operational efficiency enhancement across various industries such as manufacturing, energy, transportation, and healthcare. Hence, it illustrates the adaptable and impactful nature of these techniques in different domains (see figure 12)

5.2. Presentation of the list of activities

5.2.1. Act U.1.1: Real-time communication

The activity represents a set of case studies dealing with the development of applications that address real-time process control using communication protocols such a WebRTC and OPC-UA.

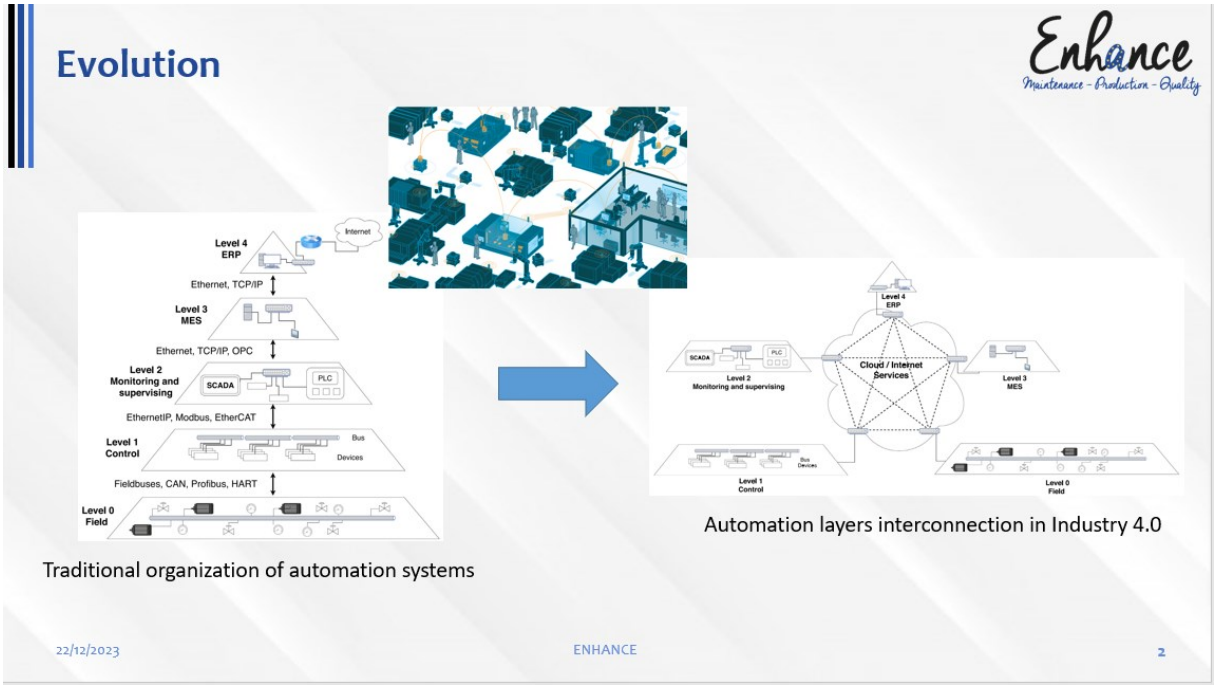

Figure 12 : Print Screen activity U.1.1

More information may be found at the learning platform at URL https://lel.eplus-enhance.eu/course/view.php?id=24 (access credentials are available for EC reviewers)

The content is organized according to the following syllabus:

Enhance	**Learning Activity Syllabus**						Co-funded by the Erasmus+ Programme of the European Union
ENHANCE Domain	Maintenance						
Skill Set	Use case						
Activity Title	**Real-time communication**						
Activity Acronym	Act_U1.1						
Activity Description	The activity represents a set of case studies dealing with the development of applications that address real-time process control using communication protocols such a WebRTC and OPC-UA.						
Keywords	Real-time communication		communication technologies		OPC-UA	WebRTC	interoperability

Teaching task related to I4.0	**Topics**		**Teaching Plan**					**Learning Path**		
	Hard Skill		**Delivery Method (gamification, case study, simulation...)**		**Teaching Material**	**Duration (Hrs)**	**Soft Skill**	**Assesment**	**If FAIL goes to**	**If PASS goes to**
UC1: WebRTC for production remote control	Use of communication technologies for web applications having real-time requirements		case study, simulation	Presentation Discussion	ppt slides, videos,	20	Problem Solving, Team working, co creation, communication,	prototyping	refienement till validation	Done
UC2_1: Real-time capable OPC-UA over TSN for distributed industrial control	communication technologies for industrial scenarios		case study, simulation	Presentation Discussion	ppt slides, videos,	20	Problem Solving, Team working, co creation, communication,	prototyping	refienement till validation	Done
UC2_2: Distributed industrial control over OPC UA	communication technologies for industrial scenarios		case study, simulation	Presentation Discussion	ppt slides, videos,	20	Problem Solving, Team working, co creation, communication,	prototyping	refienement till validation	Done

Meta Skills	Creativity, Effective storytelling, Authenticity, Adaptability, Giving and receiving feedback						
Module Outcomes	Participants will be able to		Participants will be able to				
Target Group *(students, workers...)*	Master students	SME personnels					
Assessment Method	Project report, Project presentation, Assessment rubric for teamwork, Quizzes, contest						
Teaching Material							
Equipment	high performance computer	OPC server	Fischertechnik (inc. PLC)	Databases (for real time applications)	IIoT, Sensors/actuators	Robots (if exist)	Camera
Multimedia	Lecture notes	Role play scene setup					
Content URL	Video URL						
Class requirements *(equipement that participants should bring)*	Laptopos/Notebooks/Deskt ops						
Prerequisites *(previous modules that student should attend)*	Act 1.2	Act U1.2	Act U2.3				
Total duration *(Hrs)*	40-60						

5.2.2. Act U.1.2: Data acquisition and storage in industry 4.0

This activity is addressing the enabling of proficiency in data acquisition and storage methods within Industry 4.0 through the Use Case course. It emphasizes strategies to collect, manage, and store diverse data types from multiple sources across various industrial sectors, fostering an understanding of effective data handling crucial for informed decision-making and operational optimization (see figure 13)

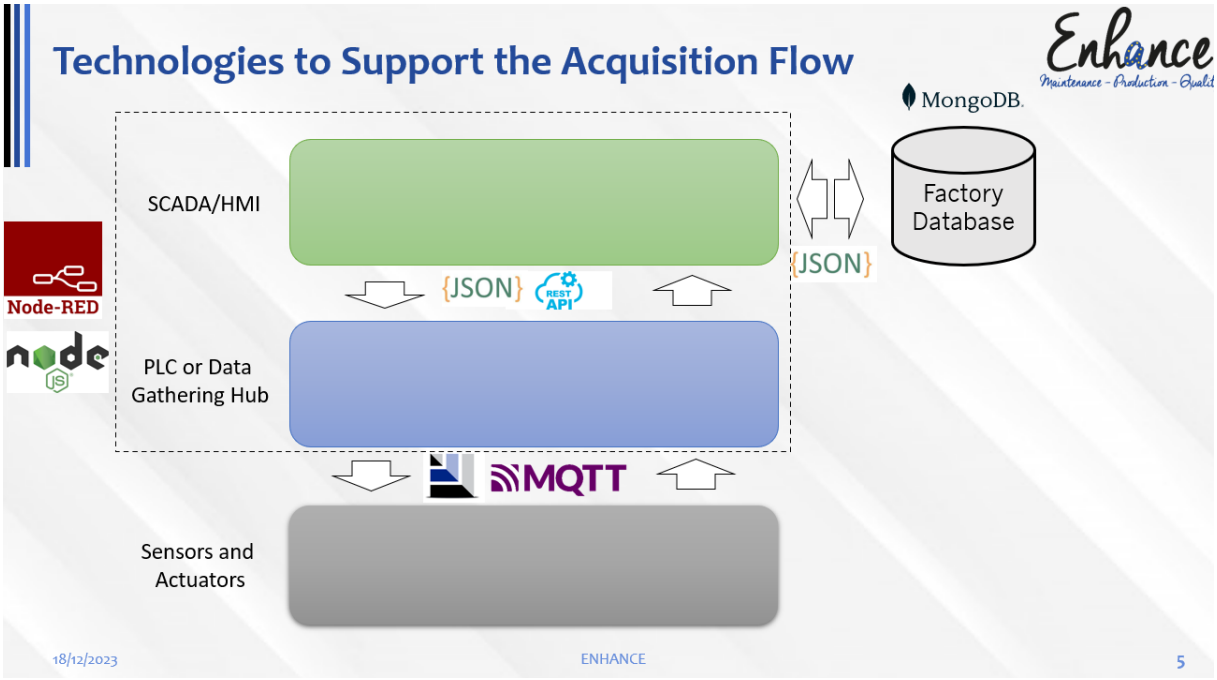

Figure 13 : Print Screen activity U.1.2

More information may be found at the learning platform at URL https://lel.eplus-enhance.eu/course/view.php?id=13 (access credentials are available for EC reviewers)

The content is organized according to the following syllabus:

Enhance Maintenance - Production - Quality	**Learning Activity Syllabus**					Co-funded by the Erasmus+ Programme of the European Union	
ENHANCE Domain	Maintenance						
Skill Set	Ability to understand and replicate typical data acquisition flow						
Activity Title	Data acquisition and storage in industry 4.0						
Activity Acronym	Act_U.1.2						
Activity Description	This activity is addressing the enabling of proficiency in data acquisition and storage methods within Industry 4.0 through the Use Case course. It emphasizes strategies to collect, manage, and store diverse data types from multiple sources across various industrial sectors, fostering an understanding of effective data handling crucial for informed decision-making and operational optimization.						
Keywords	Industry 4.0	Non-SQL storage	REST API	NodeRed	Zero-Defects Manufacturing		

Teaching task related to I4.0	**Topics**	**Teaching Plan**					**Learning Path**		
	Hard Skill	**Delivery Method (gamification, case study, simulation...)**		**Teaching Material**	**Duration (Hrs)**	**Soft Skill**	**Assesment**	**If FAIL goes to**	**If PASS goes to**
1. Typical data acquisition flow and corresponding technologies. Scenario 1 (Zero Defects Manufacturing use-case)	Understanding of a "typical" data acquisition flow and corresponding technologies that are used on various stages. First use-case follows the data acquistion flow from the first task and relies on some components developed within the ZDM Project.	Lecture, Live Demonstration	Group Discussion, Individual Assistance	ppt file, code snippets	1h 30	.Problem Solving .Critical thinking . Presentation . Infographic communication	Question 1	Task 3 (MDIS)	task 2 (SND)
2. Typical data acquisition flow and corresponding technologies. Scenario 2 (NodeRed based use-case)	Understanding of a "typical" data acquisition flow and corresponding technologies that are used on various stages. Second use-case follows the similar data acquisition flow, but relies on different technologies, such as NodeRed. Both use-cases have the same goals. First goal is to provide fundamental knowledge of the IoT-related data acquisition. Another important goal is to provide the understanding of different storage types. And finally, after data are acquired and stored, it is important to visualize data to have better insights into how they can be utilized.	Lecture, Live Demonstration	Group Discussion, Individual Assistance	ppt file, code snippets, NodeRED environment	1h				

Meta Skills							
Module Outcomes	Participants will be able to install and manage the MongoDB.		Participants will be able to understand the "typical" data acquistion flow.		Participants will be able to install and use the NodeRED environment.		
Target Group *(students, workers...)*	Master students	SME personnels					
Assessment Method	Project report, Project presentation, Live demonstration						
Teaching Material							
Equipment	sensors	NodeRED	MongoDB DBMS	ZDMP component			
Multimedia	Lecture notes	Role play scene setup					
Content URL							
Class requirements *(equipement that participants should bring)*	Computer						
Prerequisites *(previous modules that student should attend)*	N/A						
Total duration *(Hrs)*	2,5						

5.2.3. Act U.1.3: Machine Learning and application for maintenance

Predictive Maintenance (PdM) is a maintenance strategy that predicts equipment failures before they occur and then performs maintenance in advance to avoid the occurrence of failures. In PdM, prognostics is the engineering discipline which provides tools for detecting the precursors of a failure, and predicting how much time remains before a likely failure. This predicted time is what is known as Remaining Useful Life (RUL). Knowledge of system RUL allows, for example, the logistician to reduce inventory spares and affects the manpower need for maintainers and facilitates more efficient operations. Techniques that use data-driven approach to estimate RUL learn models directly from the data, rather than using a hand-built model based on human expertise. The advantage of a data-driven approach is the generality of the model, and the ability to set threshold with nominal components leading to a relative low application cost, and faster deployment of systems.

This activity will first provide a tutorial on the basics of data-driven prognostics, as a set of techniques that use pattern recognition and machine learning to detect changes in system states. Then it will provide a hands-on workshop to apply machine learning techniques on an industrial case study to detect failures occurring in a turbo-jet engine (see figure 14)

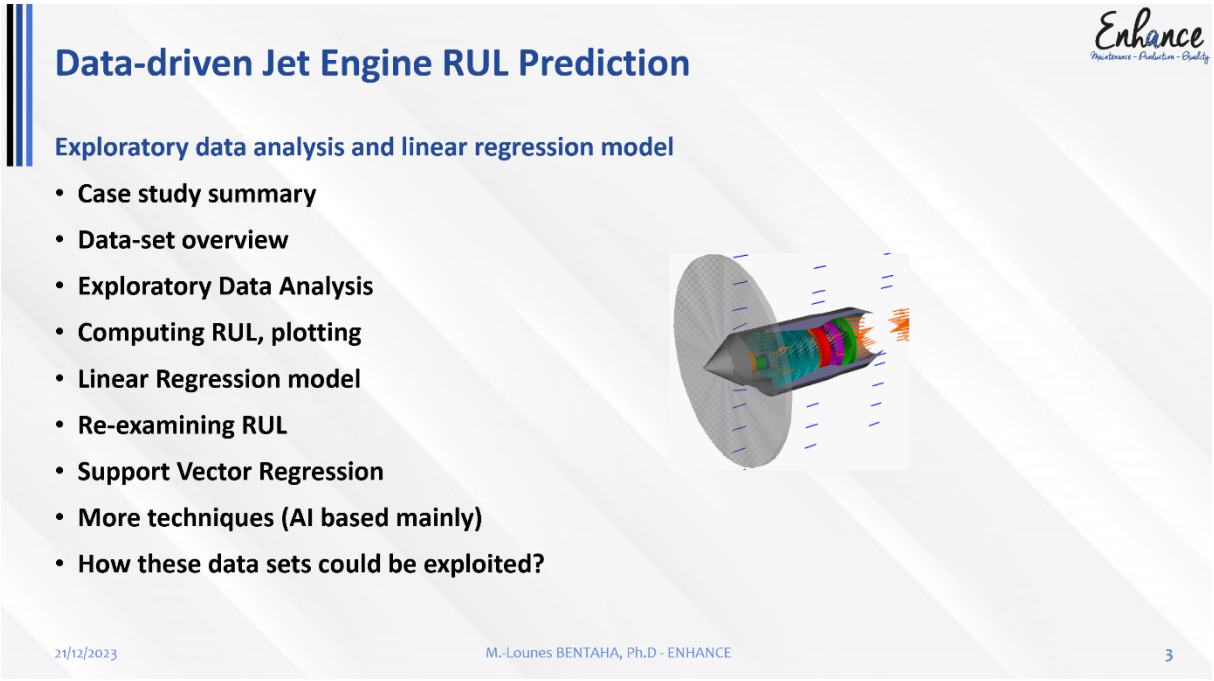

Figure 14 : Print Screen activity U.1.3 (A)

More information may be found at the learning platform at URL https://lel.eplus-enhance.eu/course/view.php?id=18 (access credentials are available for EC reviewers)

The content is organized according to the following syllabus:

Enhance Predictive - Analytics - Quality	**Learning Activity Syllabus**						Co-funded by the Erasmus+ Programme of the European Union
ENHANCE Domain	Maintenance						
Skill Set	Advanced Maintenance strategies						
Activity Title	Machine Learning and applications for maintenance 4.0						
Activity Acronym	Act_U1.3						
Activity Description	Predictive Maintenance (PdM) is a maintenance strategy that predicts equipment failures before they occur and then performs maintenance in advance to avoid the occurrence of failures. In PdM, prognostics is the engineering discipline which provides tools for detecting the precursors of a failure, and predicting how much time remains before a likely failure. This predicted time is what is known as Remaining Useful Life (RUL). Knowledge of system RUL allows, for example, the logistician to reduce inventory spares and affects the manpower need for maintainers and facilitates more efficient operations. Techniques that use data-driven approach to estimate RUL learn models directly from the data, rather than using a hand-built model based on human expertise. The advantage of a data-driven approach is the generality of the model, and the ability to set threshold with nominal components leading to a relative low application cost, and faster deployment of systems. This activity will first provide a tutorial on the basics of data-driven prognostics, as a set of techniques that use pattern recognition and machine learning to detect changes in system states. Then it will provide a hands-on workshop to apply machine learning techniques on an industrial case study to detect failures occurring in a turbo-jet engine.						
Keywords	Predictive Maintenance	Remaining Useful Life	data-driven prognostics	Machine Learning	turbo-jet engine	Scikit-Learn	Python

Teaching task related to I4.0	**Topics**		**Teaching Plan**					**Learning Path**		
	Hard Skill		**Delivery Method (gamification, case study, simulation...)**		**Teaching Material**	**Duration (Hrs)**	**Soft Skill**	**Assesment**	**If FAIL goes to**	**If PASS goes to**
Task 1: Data-driven Prognostics Prognostics and Health Management	Provide the basics of data-driven prognostics, as a set of techniques that use pattern recognition and machine learning to detect changes in system states.		Lecture	discussion	power point slides scientific articles video	4	Problem Solving Critical thinking Team working Presentation	MCQ	Iterate Task 1	Task2
Task 2: Data-driven Jet Engine RUL Prediction	Apply machine learning techniques on an industrial case study to detect failures occurring in a turbo-jet engine and predict RUL		Lecture	discussion case study	power point slides data set files first approch implementation source code files	12	Problem Solving Critical thinking Team working	MCQ	Iterate Task 2	Go to subsequent activity

Module Outcomes	Participants will be able to analyse data using basic statistcs concepts and tools.		Participants will be able to apply data based techniques for RUL estimates		Design and implement ML techniques to predict RUL and implement PdM techniques under python coding environment		
Target Group *(students, workers...)*	Master students	SME personnels	Teachers/trainers	Researchers/ Phd Student			
Assessment Method	Project report, Project presentation, Assessment rubric for teamwork						
Teaching Material							
Equipment	Computer	Python	Anaconda				
Multimedia	Lecture notes						
Content URL	No need						
Class requirements *(equipement that participants should bring)*	Computer						
Prerequisites *(previous modules that student should attend)*	Descriptive statistics	Data analysis, data preprocessing	Basics of maintenance strategies, Reliability and maintenance	Forecasting	Machine Learning and AI	Python programming, Data visualization	
Total duration *(Hrs)*	16 (Task 2 concern is ML techniques development for predictive maintenance under python coding environment)						

5.2.4. Act U.1.4: Dashboarding and data visualisation

With this activity, the objective is to empower participants in the Use Case course to master dashboarding and data visualization techniques tailored for Industry 4.0 scenarios. The activity will enable effective interpretation and communication of complex industrial data sets, fostering informed decision-making and actionable insights across diverse sectors and maintenance scenarios (see figure 15)

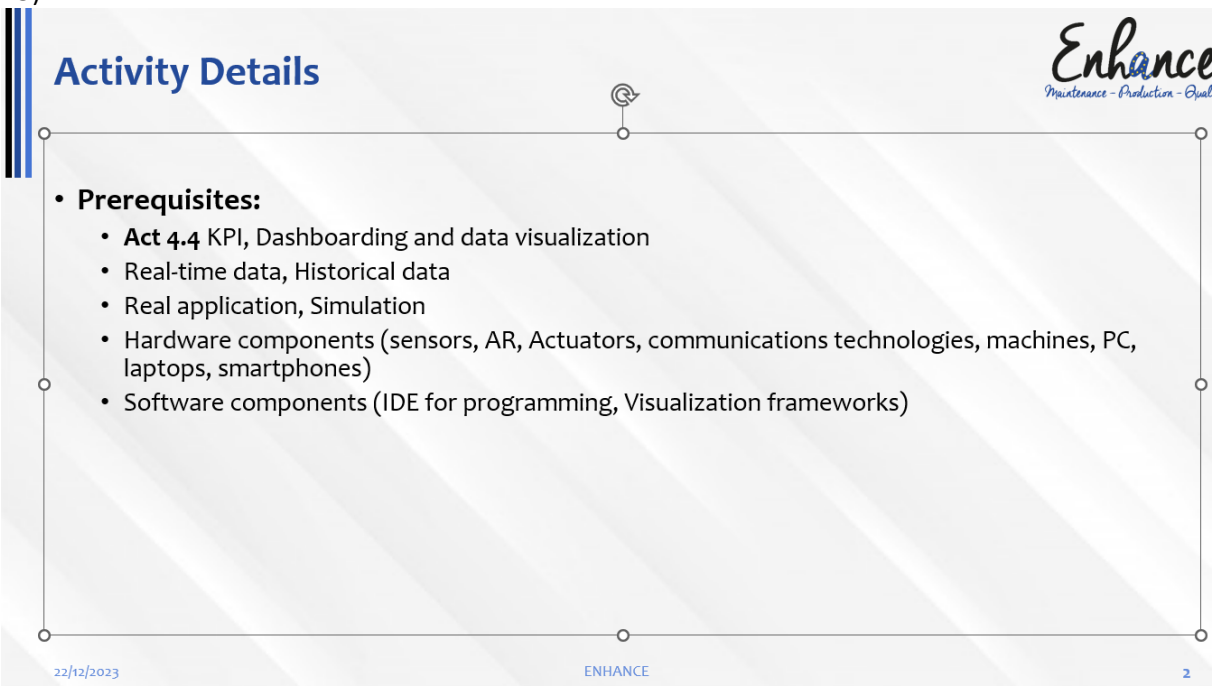

Figure 15 : Print Screen activity U.1.4

More information may be found at the learning platform at URL https://lel.eplus-enhance.eu/course/view.php?id=22 (access credentials are available for EC reviewers)

The content is organized according to the following syllabus:

Enhance	**Learning Activity Syllabus**						Co-funded by the Erasmus+ Programme of the European Union
ENHANCE Domain	Maintenance						
Skill Set	Use case						
Activity Title	**KPIs, Dashboarding and Reporting**						
Activity Acronym	Act_U.1.4						
Activity Description	With this activity, the objective is to empower participants in the Use Case course to master dashboarding and data visualization techniques tailored for Industry 4.0 scenarios. The activity will enable effective interpretation and communication of complex industrial data sets, fostering informed decision-making and actionable insights across diverse sectors and maintenance scenarios.						
Keywords	KPIs	Reporting	Dashboarding	Visualization			

Teaching task related to I4.0	**Topics**		**Teaching Plan**					**Learning Path**		
	Hard Skill		**Delivery Method (gamification, case study, simulation...)**		**Teaching Material**	**Duration (Hrs)**	**Soft Skill**	**Assesment**	**If FAIL goes to**	**If PASS goes to**
UC1: Augmented Reality – Future Interface in Maintenance	KPIs definition, Use of XR technology, Programming, Prototyping, integration,		case study	Presentation Discussion	ppt slides, videos,	20	Problem Solving, Team working, co creation, communication,	prototyping	refienement till validation	Done
UC2: Advanced Dashboards for Fischertechnik	KPIs definition, Technology selection, Programming, Prototyping, integration, Interoperability		case study	Presentation Discussion	ppt slides, videos,	20	Problem Solving, Team working, co creation, communication,	prototyping	refienement till validation	Done

Meta Skills	Effective storytelling, Giving and receiving feedback, Adaptability, Authenticity, Creativity						
Module Outcomes	Participants will be able to design of user-friendly UI applications leading to more transparency, tracebility and contributing to decision making capabilities for human workers.						
Target Group *(students, workers...)*	Master students	SME personnels					
Assessment Method	Project report, Project presentation, Assessment rubric for teamwork, prototype demonstration/validation						
Teaching Material							
Equipment	XR	IIoT, Sensors, Actuators	Simulation software	Databases	UI design tools	Cameras	Fischertechnik as industrial application
Multimedia	Lecture notes	Role play scene setup					
Content URL	Video URL						
Class requirements *(equipement that participants should bring)*	Laptopos/Notebooks/Desktops						
Prerequisites *(previous modules that student should attend)*	Act 4.4	Act 3.5	Act 4.2	Act U 1.2			
Total duration *(Hrs)*	40						

6. Conclusion

This deliverable presented two courses addressing Maintenance 4.0 topics: Course 1, focusing on Advanced Maintenance Strategies, and Course 2, addressing Integrated Maintenance Planning. These courses illuminate the path toward a transformative era in industrial maintenance. Through the integration of real-time communication, proficient data acquisition, and storage in Industry 4.0, along with leveraging machine learning for maintenance applications and KPI assessment, this initiative has propelled a new era of proactive maintenance. The inclusion of dashboarding and data visualization further enhances insights, fostering informed decision-making. This pilot not only showcases the potential of Industry 4.0 in revolutionizing maintenance practices but also emphasizes the crucial role of technology in shaping the future of industrial maintenance methodologies.

7. References

[1] Gabriel Rissola, Jens Sörvik, Digital Innovation Hubs in Smart Specialisation Strategies, Joint Research Centre (JRC),2018, 50 pages.
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