COLLABORATIVE ROBOTICS FOR CIRCULAR ECONOMY IN MANUFACTURING SECTORS

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Report: Training Content

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Content

1.Introduction

CROCEMS (Collaborative Robotics for Circular Economy in Manufacturing Sectors) is dedicated to delivering a comprehensive training program on applying Collaborative Robotics to Circular Economy processes. Their activities include comparative analyses, questionnaires, real-life case studies, blueprint definition, development of a training course, and more.

The CROCEMS course is one of the most important part of this project initiative. Consortium has delivered a comprehensive training program that blends theoretical knowledge with practical applications.

This course begins with an introductory module (0) that provides an overview of the key topics covered in the CROCEMS curriculum:

- Collaborative Robotics Basics
- Sustainability & Circular Economy in Manufacturing Sectors
- Lean Robotics Methodology
- Circular Business Models for Waste Management
- Circular Strategy Mapping & Value Networks for Waste Management
- Product Development Cycle & Ecodesign

Following the introductory module, there are specific modules for each topic, allowing you to deepen your knowledge. This course, consisting of 7 modules and 28 areas of specialization, is targeted at workers in the manufacturing sectors, as well as the unemployed, students, and other stakeholders (companies, clusters, etc.).

The course includes an introductory video, a presentation, a coursebook, and interactive solutions to assess the knowledge acquired. For each module completed (achieving over 75% on the assessment within a maximum of two attempts), participants will receive a certification.

2. Modules Overview

Module 1. Collaborative Robotics Basics

Table 1. Module 1 Overview

Content	1 introductory video; 45 slides; 197-word pages
Duration	23 hours
Target Group	• Workers in the manufacturing sector aim to enhance their skills in collaborative robotics and sustainability practices. • Unemployed individuals seeking to enter the manufacturing sector or willing to increase their skills. • Students pursuing degrees of VET courses in engineering, robotics, environmental science, and related fields. • Other stakeholders relevant such as clusters, research centres, etc.
Assessment	75% of correct answers in interactive H5P activities with a maximum of two attempts

Module 1, **"Collaborative Robotics Basics - Modular Design and Behaviour"**, will provide a comprehensive understanding of collaborative robotics, focusing on foundational concepts and practical applications.

This first module covers the foundational elements of collaborative robots with five areas which include robotics components, automation technologies, gripping technologies, safety aspects, and technical design modification (Table 2).

These five areas have been deployed in detail with the preparation of 19 units.

Module 1 includes defining and classifying collaborative and industrial robots, exploring the essential components of robotic systems, and highlighting the unique features of collaborative robots. The module covers human-robot collaboration, different models of collaborative robots, and practical techniques for bin picking operations and automated item picking. Additionally, the module delves into gripping technologies, discussing gripping principles, types of grippers, and the construction and strategic use of mechanical grippers. It also provides guidance on selecting the appropriate gripping system and models.

Safety aspects are thoroughly examined, including standards, safety measures, types of safety sensors, and safety principles specific to human-robot collaboration (HRC), along with risk assessment methods.

Finally, the module enhances the ability to read, understand, and modify technical designs. It covers implementation principles, workplace layout, integration of collaborative robots into assembly lines, and the balancing and configuration of assembly lines. This comprehensive approach ensures that learners can effectively design, implement, and manage collaborative robotic systems in various industrial settings.

Table 2. Content of Module 1

AREAS	UNITS
Robotics Components	• Introduction to Lean Robotics • Components implementation in lean methodology
Automation Technology and Collaborative Robots	• Fundamentals for bin picking operations • Automated Item Picking
Gripping Technologies	• Gripping principles and types • Construction of mechanical grippers • Selection of gripping systems and gripper models
Safety Aspects	• Standards • Safety measures • Types of safety sensors • Safety principles in Human-Robot Collaboration • Risk assessment
Ability to read, understand and modify technical designs	• Implementation principles and workplace layout • Integration of collaborative robots to assembly lines • Configuration and reconfiguration of assembly lines

Module 2. Sustainability & Circular Economy in Manufacturing Sectors

Table 3. Module 2 Overview

Content	1 introductory video; 71 slides; 234-word pages
Duration	28 hours
Target Group	• Workers in the manufacturing sector aim to enhance their skills in collaborative robotics and sustainability practices. • Unemployed individuals seeking to enter the manufacturing sector or willing to increase their skills. • Students pursuing degrees of VET courses in engineering, robotics, environmental science, and related fields. • Other stakeholders relevant such as clusters, research centres, etc.
Assessment	75% of correct answers in interactive H5P activities with a maximum of two attempts

Module 2, **" Sustainability & Circular Economy in Manufacturing Sectors"**, talk about the fundamentals of Circular Economy. The main objective of this module is to know what Circular Economy is and what is its impact on the sustainability of European manufacturing sector.

This second module delves into the standards, regulations, and processes of Circular Economy and sustainability in manufacturing sectors (Table 4).

These four areas have been deployed in detail with the preparation of 19 units.

Module 2 will learn students about the principles of Circular Economy, which focuses on minimizing waste and making the most of resources. This involves a shift from the traditional linear economy, which follows a 'take, make, dispose' model, to a more sustainable circular approach where products, materials, and resources are reused, repaired, refurbished, and recycled.

Secondly, the module will equip with the skills to assess resource use and waste generation within manufacturing companies. By understanding these aspects, students will be able to implement the 'close the loop' rule, which is a core principle of Circular Economy. This rule emphasizes the importance of creating closed-loop systems where materials are kept in use for as long as possible, extracting maximum value from them before recovery and regeneration. This not only helps in reducing environmental impact but also enhances the efficiency and sustainability of manufacturing operations.

Third, the module proposes innovative circular solutions for products, operations, processes, and services. This includes the development of new circular business models that promote sustainability and resource efficiency.

Table 4. Content of Module 2

AREAS	UNITS
Introduction into Standards and Regulation on Circular Economy and Sustainability	• Circular Economy and Sustainability • The Evolution of the term Circular Economy and Sustainability: Historical and Theoretical Perspectives • Legislative frame on European level • Standards on Circular Economy and Sustainability • Economic, Environmental, and Social Benefits of CE • Circular Economy in Manufacturing Sectors - Challenge or Possibility

Circular Economy processes and waste management processes	• Circular Economy Strategies • Collaborative robotics supporting Circular Economy (CRSCE) strategies general • CRSCE through sorting and dismantling • CRSCE through remanufacturing and reuse • CRSCE through recycling
Environmental management monitoring for CRSCE	• Principles of Environmental Monitoring • Environmental Monitoring Technologies • Data Collection and Analysis • Environmental Risk Assessment and Management
Best Practices of CRSCE	• Circular Economy • Environmental Responsibility • Social Entrepreneurship • Corporate Governance

Module 3. Lean Robotics Methodology

Table 5. Module 3 Overview

Content	1 introductory video; 38 slides; 155-word pages
Duration	19 hours
Target Group	• Workers in the manufacturing sector aim to enhance their skills in collaborative robotics and sustainability practices. • Unemployed individuals seeking to enter the manufacturing sector or willing to increase their skills. • Students pursuing degrees of VET courses in engineering, robotics, environmental science, and related fields. • Other stakeholders relevant such as clusters, research centres, etc.
Assessment	75% of correct answers in interactive H5P activities with a maximum of two attempts

Module 3, **"Lean Robotics Methodology"**, talk about lean robotics and its application at industry level. The main objective of this module is to know what Circular Economy is and what is its impact on the sustainability of European manufacturing sector.

This third module explores the integration of lean manufacturing principles with collaborative robotics to optimize processes and reduce waste. For that purpose, four areas have been deployed: robotics components; automation technology and collaborative robots; reading, understanding and modifying technical designs; software for the robotic cell task. These four areas include 13 units (Table 6).

By developing standardized procedures and guidelines, this module aims to streamline the entire deployment cycle, from design to integration and operation. Through optimization of workflows, automation of tasks, and leveraging advanced technologies, this module seeks to significantly reduce deployment times, enabling organizations to realize the benefits of robotic automation more rapidly.

Moreover, this module emphasizes the importance of ongoing refinement and waste elimination, fostering a culture of continuous improvement to ensure that deployments evolve to meet changing requirements and remain aligned with organizational goals.

Ultimately, this module aims to enhance overall efficiency, minimize waste, and accelerate time-to-value for organizations implementing robotic automation solutions.

Table 6. Content of Module 3

AREAS	UNITS
Robotics Components	• Definition and classification of industrial and collaborative robots • Components of a robotic system • Special features of Collaborative Robots • Human-Robot Collaboration • Collaborative Robots models
Automation Technology and Collaborative Robots	• Integration of automation technologies and collaborative robots according to Lean philosophy • Operation of automation technologies and collaborative robots according to Lean philosophy • Waste reduction in the operation phase according to Lean philosophy

Reading, understanding and modifying technical designs	• Robotic risk assessment in lean manufacturing • Monitoring performance according to lean philosophy • System design bad practices • Standardize
Software for the robotic cell task	• Task mapping • Robotic task mapping and arrangement • Manual-Robotic comparison • Robotic cell final design

Module 4. Circular Business Models for Waste Management

Table 7. Module 4 Overview

Content	1 introductory video; 43 slides; 101-word pages
Duration	13 hours
Target Group	• Workers in the manufacturing sector aim to enhance their skills in collaborative robotics and sustainability practices. • Unemployed individuals seeking to enter the manufacturing sector or willing to increase their skills. • Students pursuing degrees of VET courses in engineering, robotics, environmental science, and related fields. • Other stakeholders relevant such as clusters, research centres, etc.
Assessment	75% of correct answers in interactive H5P activities with a maximum of two attempts

Module 4, **"Circular Business Models for Waste Management"**, reflects the importance of circular business models in a Circular Economy.

This module covers the concepts, strategies, and tools for developing circular business models tailored to waste management. For that purpose, three main areas have been deployed (the concept of circular business model; circular business models for waste management; circular business models strategies).

These three areas have been deployed in detail with the preparation of 9 units.

This third module students will gain foundational knowledge on circular business models, including an in-depth understanding of the (circular) business model concept and the critical role these models play in the current economy. You will explore the evolution from traditional linear business models to innovative circular business models, utilizing tools such as the (circular) Business Model Canvas.

The module delves into various aspects of circular business models for waste management. You will learn about the business model innovation process, which includes stages of ideation, integration, validation, and implementation. Additionally, the module will cover value creation mechanisms in circular business models and strategies for effectively implementing these models.

Finally, the module will also discuss circular business model strategies, examining them through the lens of the value hill and resource flow. Practical tools for creating circular business models will be shared, alongside best practice examples specifically focused on waste management.

Table 8. Content of Module 4

AREAS	UNITS
The concept of (circular) business model	• Importance of Circular business models in the current economy • Understanding Business Models: From Linear to circular business models • The (circular) business model canvas
Circular Business Models for Waste Management	• Business model innovation process: Ideation, Integration; Validation; Implementation • Value creation mechanisms in circular business models • Strategy for implementing circular business models

Circular Business Model Strategies	• Circular Business Model Strategies according to the value hill and the resource flow • Tools for creating a Circular Business Model • Best practice examples for circular business models in waste management + Case Studies

Module 5. Circular Strategy Mapping & Value Networks for Waste Management

Table 9. Module 5 Overview

Content	1 introductory video; 29 slides; 86-word pages
Duration	11 hours
Target Group	• Workers in the manufacturing sector aim to enhance their skills in collaborative robotics and sustainability practices. • Unemployed individuals seeking to enter the manufacturing sector or willing to increase their skills. • Students pursuing degrees of VET courses in engineering, robotics, environmental science, and related fields. • Other stakeholders relevant such as clusters, research centres, etc.
Assessment	75% of correct answers in interactive H5P activities with a maximum of two attempts

The primary objective of Module 5, **"Circular Strategy Mapping & Value Networks for Waste Management"**, is to thoroughly analyze and comprehend the distinct characteristics and dynamics of waste, while also placing them within the wider context of business management concepts. This approach highlights the way to effectively use resources, promoting initiatives that consider not only the physical characteristics of waste but also the active involvement of stakeholders, study of value chains, and thorough performance measurement.

There are two main areas integrated in this module (Characteristics of waste and Business Management principles) and they include four and three units, respectively.

In this module, students will delve into the intricate details of circular strategy mapping, focusing on how to map and optimize value networks specifically for waste management. They will explore various methods and tools for analyzing waste streams, identifying key stakeholders, and understanding their roles and impacts within the value network. By studying the entire lifecycle of materials, from production to disposal, students will learn to design more efficient and sustainable waste management systems.

Additionally, the module will cover strategies for stakeholder engagement, emphasizing the importance of collaboration and shared responsibility in achieving sustainable outcomes. They will examine case studies and best practices to illustrate how successful companies have implemented circular strategies and value networks in their operations.

Performance measurement will be a crucial component, with an emphasis on developing metrics and KPIs to track progress and ensure continuous improvement. By integrating environmental priorities with organizational objectives, this module aims to strategically guide corporate operations towards sustainable practices.

Table 10. Content of Module 5

AREAS	UNITS
Characteristics of waste	• Waste management and reverse logistics • Priority waste streams • Integrated Management Systems and Deposit Return Systems • Recycling processes. Positive effects and limitations
Business management principles	• Stakeholder Management & Systems • Value Chain Analysis • Performance Measurement and Evaluation

Module 6. Product Development Cycle & Ecodesign

Table 11. Module 6 Overview

Content	1 introductory video; 52 slides; 156-word pages
Duration	19 hours
Target Group	• Workers in the manufacturing sector aim to enhance their skills in collaborative robotics and sustainability practices. • Unemployed individuals seeking to enter the manufacturing sector or willing to increase their skills. • Students pursuing degrees of VET courses in engineering, robotics, environmental science, and related fields. • Other stakeholders relevant such as clusters, research centres, etc.
Assessment	75% of correct answers in interactive H5P activities with a maximum of two attempts

The primary objective of Module 6, **" Product Development Cycle & Ecodesign"** explores sustainable product development cycles and ecodesign principles, emphasizing the integration of collaborative robotics.

For that purpose, there are four areas covered with the deployment of 15 units.

This module will discuss the integration of ecodesign principles into the product development cycle. This module aims to support environmental sustainability goals, ensure compliance with technical standards, and improve coherence with existing regulatory frameworks through the application of ecodesign principles.

The objectives of this module are closely aligned with the goals outlined in the Green Deal, particularly in terms of reducing resource consumption and minimizing environmental impact. By incorporating ecodesign principles into the product development cycle, we aim to ensure that product development is aligned with sustainability objectives. This includes not only the reduction of resource use but also the mitigation of adverse environmental effects.

Throughout this module, students will explore how to embed eco-friendly design elements and practices at every stage of the product life cycle—from initial conception and design, through manufacturing and use, to final disposal. This holistic approach ensures that all developed products meet the necessary technical standards for sustainability, ultimately contributing to a more sustainable and responsible production process.

Additionally, students will examine how to enhance coherence with existing regulatory instruments that govern products at different stages of their life cycle. This involves aligning product development practices with relevant environmental regulations and standards to ensure compliance and to contribute positively to broader sustainability efforts.

Table 12. Content of Module 6

AREAS	UNITS
Socio-economic trends in manufacturing	• Sustainable Production and Consumption (I4.0) • Clean technology manufacturing • Ethical manufacturing
Market research	• User-centred and marketing approaches • Circularity in the manufacturing industry • Sector analysis, challenges, opportunities and barriers/threats • Transition instruments and case studies
Product Life Cycle	• Circular/Ecodesign fundamentals • Product life cycle thinking • Product development process • CE Design guidelines - CE Designer • Design for collaborative robotics (design for automated repair, disassembly, remanufacturing)
Product Knowledge	• Products for circular trade • Circular value for your customers • New customer behaviour and practices in circular consumption

3. Conclusion

The CROCEMS initiative represents a significant advancement in equipping the manufacturing sector with essential knowledge and practical skills for integrating Collaborative Robotics into Circular Economy processes. Through a thoughtfully structured curriculum that combines theoretical foundations with real-life applications, the CROCEMS training program is well-positioned to meet the pressing demands of sustainability and efficiency in modern manufacturing.

The CROCEMS course, with its introductory and specialized modules, provides a comprehensive pathway for learners—from understanding the basics of collaborative robotics to mastering circular strategies for waste management. Each module is meticulously designed to build on the previous ones, ensuring a deep and structured learning experience. Topics range from foundational knowledge in robotics and sustainability principles to advanced applications, such as the use of circular business models and environmental monitoring for sustainable manufacturing.

The program's modular approach not only allows learners to acquire a wide range of skills but also caters to the diverse needs of various target groups, including workers, students, the unemployed, and industry stakeholders. By offering assessments, certifications, and interactive learning materials, CROCEMS enhances both learner engagement and practical competency. The certification structure, rewarding participants who demonstrate 75% mastery in each module, underlines the program's commitment to high standards and professional development.

Overall, the CROCEMS initiative stands as a valuable contribution to the Circular Economy transition in manufacturing. By promoting sustainable practices and innovative robotic solutions, CROCEMS strengthens the manufacturing sector's ability to address environmental challenges, optimize resource use, and move toward a more resilient and sustainable future. This program not only benefits individual participants but also aligns with broader sustainability goals, supporting a Circular Economy framework that can be adopted at both regional and global levels.