LCAMP

Learner Centric Advanced Manufacturing Platform

D7.1 ADMA-LCAMP FRAMEWORKS INTEGRATION

WP7 SME-VET CONNECTION

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Document summary

Document type:	Public Report
Title	Template to create LCAMP reports
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Reviewer	Iñigo Araiztegui
Date	June 2024
Document status	1
Document level	Confidential until its publication
Document description	This document describes the main features of ADMA methodology and CLF dimensions. The document analyses the connection of the CLF concept with the ADMA framework.
Cite this deliverable as:	LCAMP (2024). ADMA-LCAMP FRAMEWORKS INTEGRATION. (LCAMP deliverable D7.1. June 2024)
Document level	Public

Version management

Version	Date	Action
0.1	2024-02-09	Draft version, lay out defined
0.5	2024-02-22	Draft version with partners contributions
0.8	2024-05-03	Final version for internal revision
0.9	2024-05-24	Final version for revision process
0.95	2024-05-30	Approval by the steering committee
1	2024-06-11	Version to be uploaded on the EU portal

GLOSSARY AND/OR ACRONYMS

AGV - Automated Guided Vehicles
AR - Augmented Reality
CLF - Collaborative Learning Factory
CoVE - Centres of Vocational Excellence
DFMA - Design Failure Mode & Effect Analysis
EXAM4.0 - Excellence Advanced Manufacturing 4.0
EQF - European Qualifications Framework
ERP - Enterprise resource planning
HVET - Higher Vocational Education and Training
IALF - International Learning Factory Association
ADMA – Advanced Manufacturing Support Centre
SME – Small and Medium Enterprises
VET – Vocational Education and Training
LCAMP – Learner Centric Advanced Manufacturing Platform
KPI – Key Performance Indicator
LF – Learning Factory
DG GROW - Directorate General for Internal Market, Industry, Entrepreneurship and SMEs
EISMEA - SMEs Executive Agency
MES – Manufacturing Execution System
PLC – Programmable Logic Controllers
CAD – Computer-Aided Design
IoT – Internet of Things
I4.0 – Industry 4.0
PLM – Product Lifecycle Management
IT/OT – Information Technology / Operational Technology
APS – Advanced Planning and Scheduling
CMMS – Computerized Maintenance Management System
CIM – Computer Integrated Manufacturing
MRP – Material Requirements Planning
SCADA – Supervisory Control and Data Acquisition
HMI – Human machine interaction
CMS – Content Management System
SCM – Supply Chain Management
WMS – Warehouse Management System
HCM – Human Capital Management
PIM – Product Information Management
EU – European union
SAT – Self-Assessment Tool

EXECUTIVE SUMMARY

This report aims to look for connections between the ADMA methodology used in the digital transformation of SMEs and the CLF dimensions used to describe the morphology of the LCAMP's Collaborative Learning Factory (CLF).

This report focuses on finding connections between two key models: the ADMA methodology, which is widely used to drive the digital transformation of SMEs, and the CLF dimensions, which are central to describing the main features of the Collaborative Learning Factory (CLF), including the level of technology implementations.

By exploring the possibility of applying ADMA recommendations and approaches in the educational context by integrating ADMA concepts into the CLF dimensions, LCAMP aims to this report seeks to extrapolate concepts used to assess the digital transformation of SMEs to the conceptualization of CLFs in VET centres making them as close to reality as possible. This report seeks to enrich students' preparation for today's world of work and align technical education with market demands and emerging technology trends.

The report summarises the main features of the ADMA methodology used to support SMEs in their digital transformation process. It also summarises the CLF concept and dimensions used to analyse excellent VET institutions. Finally, a preliminary analysis is carried out in order to see possible connections between both models.

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1. INTRODUCTION

The ADMA methodology emerges as a holistic approach to guide enterprises on their journey towards digitalisation, addressing key areas of transformation. At the same time, Collaborative Learning Factories (CLFs) provide a framework for analysing and improving technical education by replicating industrial environments and providing hands-on experiences for students. In this report, we seek to draw a connection between the two models, using ADMA's experience in business transformation as inspiration, leveraging CLF dimensions to strengthen educational programmes and prepare students for the digital challenges of the future.

1.1. INTRODUCTION TO THE DIGITAL TRANSITION FOR SMES AND VET CENTRES

SMEs and VET providers face unique challenges as they embark on the path towards digital transformation. Limited resources, lack of digital skills and resistance to change are common obstacles. However, these challenges present opportunities for growth and development through strategic digital adoption.

The digital transition offers numerous benefits for both SMEs and VET centres. Productivity improvements, process simplifications and improved communication are just some of the benefits. In addition, digital tools enable personalised learning experiences, aligning education with industry demands.

A successful digital transition requires planning as well as investment. We must identify the specific needs of each case, foster a digital culture in each organisation and provide training so that people are skilled in the use of digital tools. Collaboration with technology providers and leveraging available resources will facilitate implementation.

1.2. SHORT INTRODUCTION TO THE ADMA AND CLF CONCEPTS

The ADMA methodology and the CLF concept with its dimensions will be explained extensively in this report. A brief summary is given below to help understand the concepts.

ADMA METHODOLOGY

The ADMA methodology, launched by the EU-funded project ADMA (running from 2018 to 2021), is emerging as a suitable solution as it offers a holistic approach to support SMEs across seven transformation areas, aligning well with the principles of Industry 5.0.

LCAMP project's Work Package 7 focuses on integrating ADMA methodology, through a synergy with the ADMA TranS4MErs project (running from 2021 to 2024), whose aim is to assist factories in becoming 'Factories of the Future'. The ADMA TranS4MErs methodology emphasizes the transformation plan and its implementation, introducing the role of the TranS4MErs to guide SMEs through their transformation journey. The ADMA TranS4MErs approach facilitates the matching between an SME and a TranS4MEr, who acts as a trusted advisor throughout the transformation journey. This journey comprises several stages, including registration, scan, debrief session, transformation plan creation, and implementation.

ADMA methodology serves as a valuable tool for SMEs venturing into digital transformation, offering a roadmap to success in the digital, ecological, and societal realms, paving the way for a future of innovation and competitiveness.

ADMA methodology takes into account 7 transformation areas related to Advanced Manufacturing: Advanced Manufacturing Technologies, Digital Factory, ECO Factory, End-to-end Customer Focussed Engineering, Human Centred Organisation, Smart Manufacturing, Value Chain Oriented Open Factory.

CLF CONCEPT

A Collaborative Learning Factory (CLF) is a specialized educational environment designed to replicate industrial settings and provide hands-on learning experiences for students, particularly in fields like Advanced Manufacturing. The CLF concept aims to bridge the gap between theoretical knowledge and practical application by immersing students in real-world production processes within educational settings, such as Vocational Education and Training (VET) centres. In a CLF, students engage in activities that simulate authentic industrial processes, allowing them to apply their knowledge in a practical, learning-centered environment. These activities often involve designing and manufacturing products, optimizing production processes, and managing supply chains, among other tasks relevant to the industry. CLFs offer a unique opportunity for skills development, innovation and collaboration in Advanced Manufacturing.

A CLF can be described taking into account 8 dimensions: Operational Model, Purpose and Target, Process, Setting, Product, Didactics, Metrics, and Collaboration.

- Operational model: CLFs require robust operational models covering financial, personnel, and thematic aspects. Adequate funding is crucial, and various models can be explored. Personnel must possess technical and didactic skills.

- Targets and purpose: CLFs serve both students and workers, offering immersive learning experiences and continuous professional development in advanced manufacturing.
- Process: The CLF process includes four stages, Product Design, Process Engineering, Manufacturing, and Supply Chain Management, simulating real-world scenarios.
- Setting: Configuration is determined by technological infrastructure, user types, and competencies.
- Product: The selected product influences competencies and technologies.
- Didactics: Focus on standardized competency frameworks.
- Metrics: Metrics evaluate effectiveness, including the number of implemented Industry 4.0 technologies, collaborative developments, and student satisfaction.
- Collaboration: Collaboration among participants is fundamental, fostering innovation and skills development.

1.3. MOTIVATION TO INTEGRATE ADMA AND CLF

The connection between the ADMA methodology and the CLF dimensions offers a unique opportunity to enrich VET. Since the ADMA methodology is a valuable tool for advancing the digital transformation of SMEs, it is interesting to be able to apply its concepts to promote the digital transformation of educational environments such as VET centres.

By adapting ADMA recommendations and approaches to the educational context, we can improve students' preparation for today's world of work by aligning educational programmes with market demands and emerging technology trends. Integrating ADMA concepts into the CLF dimensions allows us to leverage the expertise and best practices developed for SMEs and apply them effectively in the educational setting, providing students with a more relevant and up-to-date education that will prepare them for success in the digital age.

2. ADMA FRAMEWORK

2.1. FROM ADMA TO ADMA TRANS4MERS

After conducting a study on recent methodologies helping SMEs in their technological innovation process, we found that the ADMA methodology could be suitable for VET teachers while also supporting SMEs in their environment and on their way to technological innovation, providing knowledge both in the classroom and in the companies. To this end, it was necessary to carry out field research to see first-hand that the ADMA methodology was the right one to introduce within the LCAMP project.

Launched by the Directorate General for Internal Market, Industry, Entrepreneurship and SMEs (DG GROW), the European Innovation Council and the Executive Agency for Small and Medium-sized Enterprises (EISMEA) of the European Commission in 2018, the Advanced Manufacturing Support Centre developed an assistance methodology for SMEs that is very well aligned with the main ideas of the Industry 5.0 paradigm. In its 7 transformation areas, ADMA defines a holistic approach encompassing technological and non-technological aspects.

Figure 1: ADMA dimensions.

ADMA methodology described a one-stop-shop approach to SME support in 4 phases (vision and ambition, registration and scan, transformation plan and implementation plan).

The Work Package 7 of LCAMP is aimed at working with ADMA methodology. On October 1, 2021, the scale up of the ADMA EU-funded project started, under the name of ADMA TranS4MErs. The project's objective is to support factories to become 'Factories of the Future', considering the ecological, digital and societal challenges involved.

LCAMP coordinator, Tknika, has signed a Memorandum of Understanding with ADMA TranS4MErs coordinator, Irish Manufacturing Research (IMR), thanks to the intermediation of AFIL (which is partners in both projects). In line with this, at the beginning of 2023, a first group of LCAMP partners were certified as ADMA TranS4MErs after completion of the training course organized *ad hoc* by IMR.

The ADMA TranS4MErs methodology follows ADMA, but emphasizes the importance of the transformation plan and its implementation. It introduces the TranS4MEr role, which is essential in this process as they assist SMEs throughout their transformation journey. TranS4MErs have a comprehensive understanding of the specific challenges that SMEs face and the most appropriate tools to use for their transformation. Together with the SME, during the Design Phase (which starts with the ADMA scan), the TranS4MEr co-creates the Transformation Plan (TP), which prioritizes implementation and jump-starts the SME's transformation process. This is a crucial step where the SME establishes a relationship with the TranS4MEr and receives guidance on how to use the virtual xChange platform to seek out domain experts and toolkits, as well as to address the priority challenges listed in the ADMA Transformation Plan. In the Revamp Phase, the SME receives tokens from the voucher system, which they can use to pay for education modules, tech tools, expert advice and other resources. This provides SMEs with access to the necessary resources to implement their Transformation Plan and to become a 'Factory of the Future'.

It is fundamental that TranS4MErs (and companies) are continuously updated on the main technological trends in Advanced Manufacturing. In this sense, the LCAMP project itself has activities of relevant interest, such as the reports developed by the Observatory under WP3.

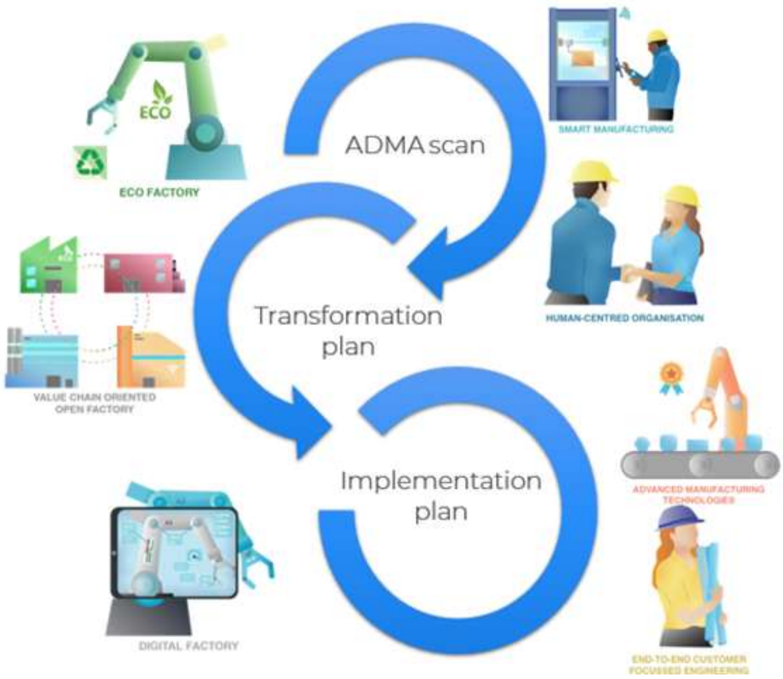

Figure 2: The ADMA TranS4MErs three-step approach.

2.2. THE ADMA METHODOLOGY AND THE SME JOURNEY

The primary objective of ADMA TranS4MErs is, therefore, to assist SMEs across Europe to become companies that can successfully navigate the digital, ecological, and societal challenges and remain competitive: 'Factories of the Future'. Through the ADMA TranS4MErs Open Calls, selected SMEs start being part of a Transformation Programme, where they will receive support and guidance to make the right choices and stay on track. Therefore, to ensure that each SME receives the necessary assistance, each company will be matched with a TranS4MEr, who will be their contact throughout the transformation journey. The TranS4MEr will provide valuable assistance and guidance, ensuring that the company is well-equipped to face the challenges ahead.

The SME journey comprises various stages, including the link to the TranS4MEr match, voucher applications and service selections. These steps are described below:

- Step 1, the SME registers on F6S platform.
- Step 2, the SME applies for the Design Voucher, which will enable the SME to be matched with a TranS4MEr and create a Transformation Plan.
- Step 3, if selected for the Design Phase, the SME will be matched with a TranS4MEr of their choice on the xChange platform. The TranS4MEr is a trained person who will be the helping hand/trusted advisor and guide the SME throughout the journey. The TranS4MEr may support the company also during the scan process.
- Step 4, the SME takes the ADMA scan, which is a questionnaire that uncovers strengths and weaknesses in 7 areas related to Advanced Manufacturing (Advanced Manufacturing Technologies, Digital Factory, ECO Factory, End-to-end Customer Focussed Engineering, Human Centred Organisation, Smart Manufacturing, Value Chain Oriented Open Factory).
- Step 5, after completing the scan, the SME has a debrief session with the TranS4MEr to go over the results of the assessment and relate them to the SME's situation. During this phase, after priorities are discussed, the TranS4MEr draft a Transformation Plan. This document analyses the SMEs transformation maturity in the 7 areas, identifies opportunities for change and selects one or two areas, where the transformation journey should begin. It is discussed and reviewed with the SME to reach the final plan. Then the TranS4MEr drafts the Implementation section, which goes into more detail about the selected areas. Based on the analysis of potential solutions and conclusions made to match specific objectives, the TranS4MEr guides the selection of services and training opportunities, that the SME may benefit from in its transformation journey and help set the KPIs.
- Step 6, the SME submits the Transformation Plan for evaluation, which simultaneously serves as the application for a Revamp Voucher.
- Step 7, if the SME is admitted to the Revamp Phase, the actual implementation will begin with confirming the services included in the plan and then accessing them through xChange platform.

Ideally, while training and other actions are taking place, the TranS4MEr is on stand-by to hear about the learning and suggest the next step. After the implementation, KPIs are measured and included in the SME Progress tracking, which has two recipients: the SME to support its journey and the Program Management to support the program development. SMEs who do not wish to apply for vouchers can still embark on a transformation journey. After registering, they can bypass the voucher application process and proceed directly to taking the scan and perusing the services catalogue to select those they wish to use. They can then contact the service provider directly and make their own arrangements (since the no voucher will cover the costs). If an SME chooses to follow the supported voucher scheme journey, the TranS4MEr will also assist them in collecting a success story that can inspire new users. The feedback obtained will help TranS4MErs, service providers and program managers to improve their services and processes. The SME will conclude the transformation journey within this framework, but the intention is for the journey to continue beyond that point.

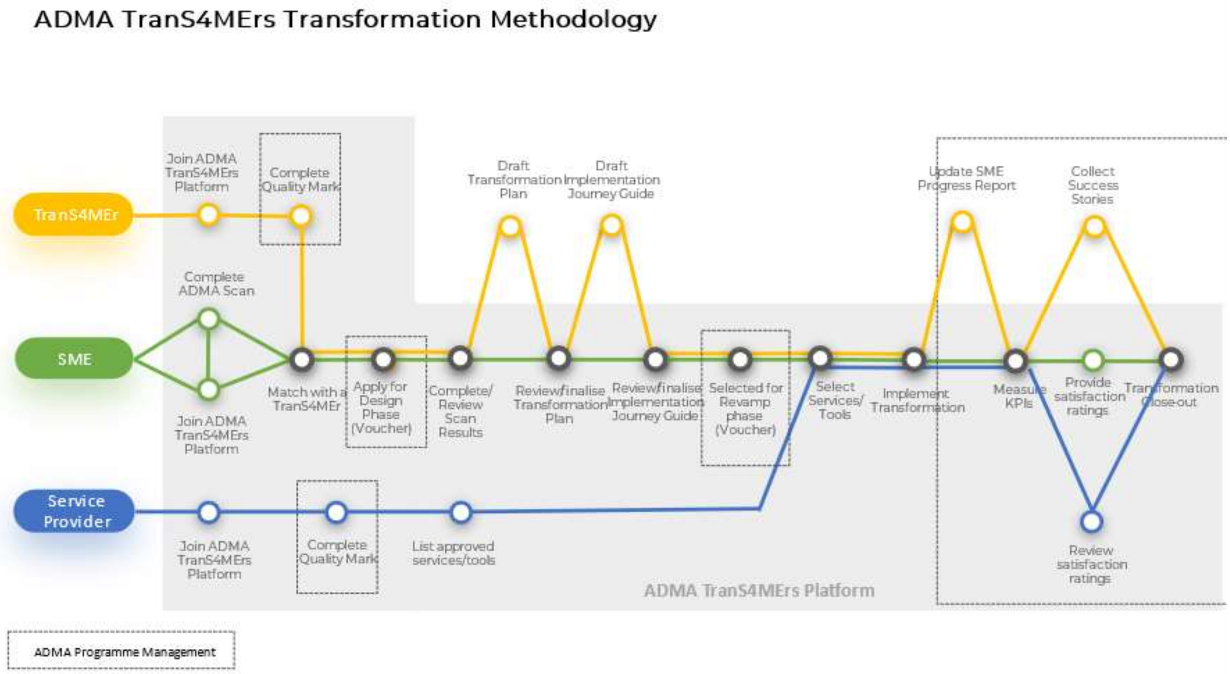

Figure 3: Journey map - a frame for the improved methodology.

2.3. INSIGHTS FROM THE FIELD RESEARCH

Knowing the value that could be obtained by the ADMA TranS4MErs project and its methodology of scanning SMEs implementing innovation, , a field research was carried out under LCAMP WP4. Within this task, 15 ADMA TranS4MErs partners have been interviewed by LCAMP partners between May and June 2023. The countries covered were Austria, Bulgaria, Czech Republic, Denmark, France, Finland, Germany, Ireland, Italy, Latvia, Lithuania, Romania, Slovakia, Spain.

It was very interesting to conduct interviews and hold conversations with the TranS4MErs who have already started collaborating with companies. A deep insight into the reality and impact of ADMA has been gained through a survey of 13 different questions aimed to tackle the obstacles that the companies face when starting they digital transformation journey and to understand where and how this journey could be improved.

During the interviews with ADMA experts, in fact, essential knowledge has been gained about the principles, applications and benefits of this methodology. It was possible to understand how

ADMA is based on the use of advanced technologies in manufacturing processes, such as automation, robotics, data analysis and Artificial Intelligence among others.

More specifically, these in-depth interviews provided valuable insight into both the strengths and challenges of the ADMA methodology. Identifying the next steps in SMEs' digital transformation journeys is crucial. This clarity provides SMEs with a tangible roadmap, helping them navigate resource and financial considerations. Many SMEs struggle with defining actionable steps despite having clear objectives. Understanding these gaps often prompts companies to initiate their digital transformation journey. These interviews also gave a perspective on why some companies didn't start their digital transformation journey yet. Common reasons include difficulties in knowing where to begin, uncertainty regarding advisory support, time constraints, resource limitations and a lack of awareness of the potential benefits. Additionally, the scarcity of skilled workforce may contribute to postponing digital transformation, but, ultimately, it is commonly agreed by the TranS4MErs that the management's lack of skills and vision is what hinders progress. It is important that the need for change originates from management, a sense of urgency and a willingness to embrace change are indispensable. The ADMA scan serves as the initial step in assessing the need and opportunity for digitalisation. Therefore, it requires someone well-versed in both technical and business aspects of SMEs. Ideally, this role is best suited for individuals like CEOs or production managers who possess the necessary expertise and insights into the company's operations.

Furthermore, interviewees widely agree that the ADMA methodology is a helpful tool for SMEs venturing into digital transformation, as it assists them in understanding where they currently stand and lays the groundwork for building a digital setup. By highlighting areas that need improvement or has potential for growth, and assessing a company's readiness for change, ADMA helps companies prioritize their digital transformation initiatives.

However, in order for the scan to be effective, it isn't enough for the TranS4MEr to have just expertise in ADMA. This expertise should, in fact, be accompanied by an existing knowledge in manufacturing, as ADMA is a tool that helps structure and enrich the consultants' understanding of production techniques. This mix of knowledge will enable consultants to guide manufacturing companies effectively through digital transformation. In fact, the ADMA methodology is specifically designed to build upon existing knowledge of production and manufacturing techniques. Without a solid understanding of these foundational concepts, it would be challenging to effectively utilize the methodology. It is necessary for the TranS4MEr to have certain requirements to carry out ADMA scans effectively. This adds value and quality to the dialogue during the ADMA scans. Having a solid understanding of manufacturing processes allows the TranS4MErs to have more meaningful discussions, provide relevant insights and offer tailored recommendations for digital transformation within the manufacturing context. Therefore, the TranS4MErs should have some specific features.

- An excellent understanding of the scan itself, to explain the structure and how it should be filled out efficiently and effectively for the benefit of the company.
- The ability to provide concrete and suitable examples for each level, tailored to the SME being analysed, in order to assist them in evaluating themselves in the best possible way.
- Critical thinking, which involves analysing and reasoning about the given responses to ensure they align with the company's reality. It also includes verifying that the person completing the questionnaire truly understands the questions, since without a good comprehension of the inquiries, it is impossible to provide accurate answers for their own company.

If, on the one hand, the knowledge of the TranS4MErs is crucial to obtain good results, on the other it is important to acknowledge the strengths and weaknesses of this methodology.

Below a summary of the strengths and weakness of the ADMA methodology that have been identified by the interviewees.

- Strengths:
    - Structure: the organization of the methodology into levels allows companies to understand their current position and potential for growth.
    - Qualitative significance: each level is accompanied by a description that helps companies grasping the implications of being at that particular level, and therefore gives a qualitative meaning to the quantitative aspects.
    - Standardization: by creating a standardized methodology, companies are able to compare themselves with other European SMEs, fostering benchmarking and knowledge exchange.
- Weaknesses:
    - Lengthy process: the long version scan is unnecessarily long and the fact that it is just in English is an obstacle. However, some linguistic versions are available.
    - Access issues: the TranS4MEr doesn't have immediate access to the results of the scan of the SME he worked with, but only when the company gives him the access, which makes the process slower than it should be.
    - Subjectivity: results may vary depending on the consultant, affecting objectivity.

The TranS4MErs agreed that it is useful to identify the next steps in the digital transformation journey of SMEs, as it allows companies to have a concrete and tangible understanding of the path they need to take, both in terms of resource and financial efforts. They often encountered companies with clear objectives, but with a strong difficulty in outlining the steps to be taken (such as activities to be carried out, involvement of external resources and adoption of technologies) to achieve those objectives. In some cases, the company think about starting a digital transformation journey once they understand they are lacking.

3. COLLABORATIVE LEARNING FACTORY

Learning Factories facilitate a practical way of teaching, offering specialized learning environments that replicate industrial settings and provide hands-on learning experiences for students. They are designed to simulate industrial processes and allow students to apply the knowledge they have acquired in a practical, learning-centred milieu. (Abele E. et al., 2015).

The LCAMP CLF description is based on eight dimensions described in *Morphology of the LCAMP collaborative learning factory (LCAMP, 2023)*.

The CLF recreates authentic industrial processes within educational settings, specifically in the laboratories of VET centres. It comprises both established and evolving LFs situated across seven geographically diverse VET centres. Each centre plays a distinct role in the production of a common final product. The interconnectedness among these distributed Learning Factories forms the operational framework of the entire CLF.

Concerning the LCAMP's CLF framework, it describes the features of the CLF using 8 dimensions: Operational model, Purpose and target, Process, Settings, Product, Didactics, Metrics, and Collaboration.

3.1. OPERATIONAL MODEL

Operating a Learning Factory goes beyond merely possessing the necessary equipment. These facilities are instrumental in developing competencies across all levels of the value chain, spanning various technological and organizational domains. To ensure the sustained operation and improvement of a Learning Factory, it must be integrated into a robust operational model encompassing financial, personnel, and thematic considerations.

Securing adequate funding is crucial for establishing and maintaining a Learning Factory. This necessitates both initial investment for facility setup and continuous financial support for ongoing operations. Funding sources may include internal resources, public grants, and contributions from third-party entities such as companies. Various funding models, ranging from short-term to long-term arrangements, can be explored to support Learning Factory initiatives. Additionally, revenue generation through market-oriented training programs, offered either through open models like club memberships or through tailored courses for individual companies, can serve as an important financing avenue.

The quality and effectiveness of a Learning Factory hinge not only on its technical infrastructure but also on the competence and organization of its personnel. In addition to possessing technical expertise, staff members must demonstrate proficiency in didactic skills to effectively develop and facilitate training programs or mentor trainees. It is imperative to recruit and cultivate suitable personnel, including research assistants, engineers, and other relevant professionals, to ensure the successful operation and continuous improvement of the Learning Factory concept (Abele E. et al., 2015).

The operational model of the CLF is closely linked with the statutes of the LCAMP alliance established in Work Package 2 (WP2) of the project. These statutes provide the fundamental guidelines and regulations governing the operation and management of the alliance, including aspects related to collaboration among partners, decision-making processes, intellectual property rights, and resource distribution.

For a more detailed understanding of the operational model of the CLF and its integration with the statutes of the LCAMP alliance, it is recommended to review specific reports related to this topic available within the project documentation. These reports will provide a comprehensive insight into how the operations of the CLF have been defined and structured in relation to the alliance statutes, ensuring consistent and effective alignment between both parts of the project.

3.2. TARGETS AND PURPOSE

The CLF targets two primary audiences: students and workers. This innovative educational concept aims to bridge the gap between theoretical knowledge and practical application in the realm of Advanced Manufacturing. By catering to the needs of both students seeking VET and professionals seeking continuous skill development, the CLF serves as a versatile platform for learning and collaboration. Through its multifaceted approach, the CLF addresses the diverse learning requirements of these two distinct yet interconnected groups, ultimately fostering a dynamic ecosystem of knowledge exchange and skills enhancement.

For VET students, the practical approach of the CLF provides an immersive and relevant learning experience. By leveraging I4.0 technologies and the operational infrastructure of the CLF, students have the opportunity to develop advanced technical skills in a realistic environment. This enables them to acquire job-specific competencies as well as cross-cutting skills such as teamwork, problem-solving, and adaptability, making them better prepared for integration into the workforce.

Moreover, the customization of courses to meet the needs of VET students ensures that the content is relevant and applicable to their future careers. Collaboration among VET centres within the framework of the CLF also opens up opportunities for knowledge exchange and best practices sharing among students and educators from different backgrounds, further enriching their educational experience.

For employees of companies, the CLF offers opportunities for continuous professional development and skills upgrading in the field of Advanced Manufacturing. By engaging in collaborative production activities and course development, employees can expand their knowledge and expertise in specific areas of I4.0, such as process digitalisation, robotics, and additive manufacturing.

The connection between the CLF and companies provides a practical learning environment where employees can directly apply what they learn to their daily work. Additionally, the international collaboration facilitated by the CLF can enable employees to access new perspectives and approaches from other countries, enriching their skill set and allowing them to stay up to date with the latest trends and technologies in their field.

In summary, for both students and employees, the CLF offers a unique platform for skills development, innovation, and collaboration in the realm of Advanced Manufacturing.

3.3. PROCESS

The proposed value chain for the CLF is designed to optimize the learning experience and practical application for students and workers alike. It comprises four integral processes: Product Design, Process Engineering, Manufacturing, and Supply Chain Management. Each of these processes plays a crucial role in simulating real-world manufacturing scenarios within the educational environment of the CLF.

- **Product Design:** This initial stage involves conceptualizing and designing the product that will be manufactured within the CLF. Students and workers collaborate to develop innovative product ideas, considering factors such as functionality, aesthetics, ecodesign and manufacturability. By engaging in product design activities, participants gain valuable insights into the iterative design process and the importance of user-centered design principles.
- **Process Engineering:** Once the product design is finalized, the focus shifts to process engineering, where students and workers determine the most efficient and effective manufacturing processes. This involves analysing the production requirements, selecting appropriate materials and technologies, and optimizing workflow sequences. Through hands-on experimentation and problem-solving, participants learn how to streamline manufacturing processes and improve productivity.
- **Manufacturing:** With the process parameters defined, manufacturing activities commence within the CLF. Students and workers work collaboratively to produce the designed product, utilizing a combination of traditional manufacturing techniques and cutting-edge technologies. This stage provides participants with practical experience operating manufacturing equipment, executing production schedules, and ensuring quality control standards are met.
- **Supply Chain Management:** The final stage of the value chain focuses on managing the flow of materials and resources throughout the manufacturing process. Students and workers learn about the complexities of supply chain management, including sourcing raw materials, managing inventory levels, and coordinating logistics operations. By understanding the interconnectedness of the supply chain, participants gain insights into the importance of efficient resource allocation and risk mitigation strategies.

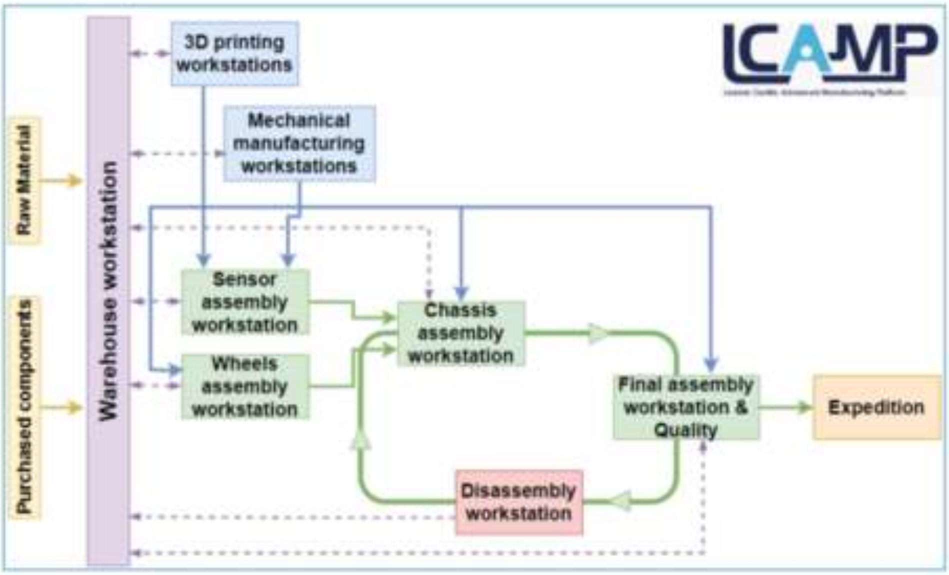

Figure 4: CLF Manufacturing process.

Throughout the entire value chain, the digital infrastructure of the CLF serves as a critical enabler, facilitating communication, collaboration, and data exchange among participants. Digital tools and technologies are integrated into each stage of the process, allowing for real-time monitoring, analysis, and optimization of manufacturing operations. This digital connectivity enhances the overall learning experience within the CLF, enabling participants to develop digital literacy skills and adapt to the evolving demands of I4.0.

3.4. SETTING

Taking into account the CLF process, the competencies each LF aims to develop, and the selected product, each regional LF must determine its configuration. It is essential to consider the technologies you have and want to teach, the type of user you will have, and the competencies you want to teach, and then see if together, they complete the entire CLF process.

Firstly, each regional LF needs to assess its existing technological infrastructure and capabilities. This includes identifying the equipment, software, and facilities available for manufacturing and teaching purposes. It's crucial to ensure that the LF has the necessary resources to support the integration of Industry 4.0 technologies into the manufacturing process and provide hands-on training to students and workers.

Next, the LF must consider the type of user it will cater to. This could include vocational students, industry professionals, or a combination of both. Understanding the needs and skill levels of the target audience will help tailor the LF's configuration to meet their specific requirements.

Finally, the LF must align its configuration with the competencies it aims to develop. This involves identifying the key skills and knowledge areas that participants should gain from their experience in the LF. For instance, if the LF aims to develop competencies in robotics and automation, it may need to invest in robotic arms, PLCs (Programmable Logic Controllers), and simulation software. Similarly, if the LF aims to develop competencies in additive manufacturing, it may need to provide access to 3D printers and CAD (Computer-Aided Design) software.

Once each regional LF has determined its configuration based on these factors, they can then collaborate to ensure that together, they cover the entire CLF process. This may involve sharing resources, expertise, and best practices to create a comprehensive and cohesive learning environment. By working together, regional LFs can leverage their unique strengths and capabilities to provide participants with a well-rounded and impactful learning experience within the CLF framework.

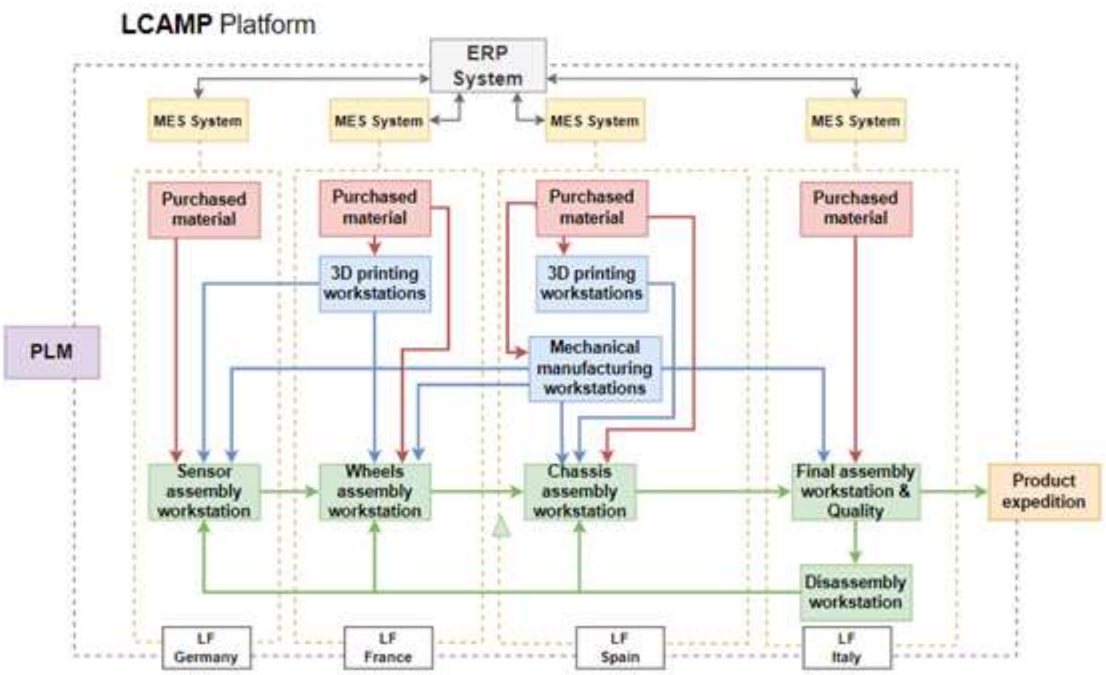

Figure 5: Example of a CLF operative.

In the example shown in the picture above, four LFs located in Germany, France, Spain, and Italy collaborate to manufacture the robots for the CLF, showcasing how a combination of LFs can fulfil the CLF process.

Germany and Italy, for instance, may work with parts manufactured in France and Spain. In terms of manufacturing processes, while France focuses on additive manufacturing through 3D printing, Spain also incorporates machining. Each country takes responsibility for at least one assembly station.

Data generated in each LF will be collected in an individual Manufacturing Execution System (MES) connected to a joint Enterprise Resource Planning (ERP) system. This setup enables the monitoring of production in each country.

Participants, whether students or workers, can collaborate on orders, manufacturing times, and shipping, fostering a cohesive and efficient workflow. This collaborative approach not only enhances the learning experience within each LF but also promotes cross-border cooperation and knowledge exchange among participants from different cultural and educational backgrounds. Moreover, by utilizing a shared ERP system, all stakeholders have access to real-time production data, enabling them to make informed decisions and optimize manufacturing processes collaboratively.

3.5. PRODUCT

The product plays a crucial role in the development of the CLF. The manufacturing processes and applied technologies will have a significant impact on the various competencies that will be addressed.

Firstly, the chosen product determines the manufacturing processes to be implemented in the CLF. Each product has unique manufacturing requirements that may include machining techniques, assembly methods, welding, 3D printing, among others. These manufacturing processes provide opportunities for CLF participants to acquire specific technical skills related to the production of that particular product.

Additionally, the product selection also influences the technologies applied in the CLF. For instance, if the chosen product requires the use of I4.0 technologies such as the Internet of Things (IoT), Augmented Reality (AR), or additive manufacturing, then CLF participants will have the opportunity to become familiar with and work with these cutting-edge technologies. This will provide them with hands-on experience of how these technologies can enhance manufacturing processes and increase efficiency in a real industrial setting.

In addition to technical skills, the chosen product can also impact the development of soft skills such as teamwork, problem-solving, and innovation. For example, if the product is complex and requires significant collaboration among participants for its design and manufacturing, then teamwork and effective communication will be fostered. Similarly, if the product presents challenging technical issues to solve, participants will have the opportunity to develop problem-solving skills and critical thinking in a practical environment.

In this case, for the first CLF, a product has been selected that not only allows for the integration of I4.0 technologies into the manufacturing process but also allows these technologies to be incorporated directly into the product itself.

The selected product is an automated robot designed to meet the specific requirements for the development of the CLF. It is equipped with sensors for intelligence and communication tools for collaboration. The robot consists of two main boards, one upper and one lower, which form the chassis. The lower board houses components such as the battery pack, motors, and single-board computer, while the upper board accommodates other components. There are two main versions of the robot, depending on the traction system (2 Omni wheels and 2 standard wheels, with only two motors for the two standard wheels as a differential drive robot; four Mecanum wheels with one motor per wheel), and there is the possibility of inserting different sensors for various areas of use or purposes.

This robot serves as an ideal product for the CLF due to its versatility and adaptability. By incorporating sensors and communication tools directly into the robot, participants in the CLF can not only learn about the manufacturing process but also gain hands-on experience with I4.0 technologies such as IoT and collaborative robotics. Additionally, the modular design of the robot allows for customization and experimentation, enabling participants to explore different configurations and applications.

Furthermore, the robot's functionality aligns well with the objectives of the CLF, which aims to provide practical, project-based learning opportunities for students and workers. By working with the robot, participants can develop a wide range of skills, including programming, electronics, mechanical design, and project management, all of which are highly relevant in today's manufacturing industry.

Overall, the selection of this robot as the product for the first CLF not only facilitates the integration of I4.0 technologies but also provides a rich learning experience for participants, making it an ideal choice for advancing the goals of the CLF initiative.

3.6. DIDACTICS

The LCAMP CLF has been meticulously crafted to streamline the acquisition of competences essential to Advanced Manufacturing, fostering an optimal learning environment. Consequently, the entire structure of the CLF is intricately linked with these competences, ensuring a cohesive and effective educational experience.

A LF serves as a comprehensive learning environment, facilitating the acquisition of competences across various knowledge domains. Within the realm of I4.0, the LCAMP consortium CLF has specifically identified technological domains aligned with national qualifications systems from partner organizations. These selections are informed by the insights gathered through LCAMP's Observatory (WP3) and VET-SME collaboration (WP7), ensuring that the CLF curriculum is tailored to meet industry demands and emerging trends.

When designing courses within the CLF, it is essential to establish a common educational approach and terminology. This is where the LCAMP Competence Framework for Advanced Manufacturing, established in WP5, comes into play. This framework provides partners with a standardized set of guidelines for determining specific technical and transversal skill sets, course content, delivery methods, and assessment methods for selected courses. By adhering to this framework, partners can ensure consistency and coherence in course design and delivery, ultimately enhancing the effectiveness of the CLF in preparing learners for the demands of the modern manufacturing landscape.

3.7. METRICS

The metrics section outlines quantitative measures that are easily identifiable, such as the floor area size, the average number of participants per training session, or the count of full-time researchers dedicated to the LF. Its purpose is to provide users of the descriptive model with a clearer understanding of the physical and operational scope of the analysed LF. By incorporating these specific metrics, stakeholders can gain a more vivid perception of the scale and capabilities of the facility, aiding in decision-making processes and strategic planning initiatives.

These are the metrics that will be considered when evaluating our CLF:

- **Number of I4.0 technologies:** This metric will assess the incorporation of I4.0 technologies into our CLF, aiming for a total of 20 technologies implemented.
- **Quantity of collaborative product developments between project partner LFs:** This metric focuses on fostering collaboration between LFs, aiming to achieve 8 collaborative product developments among project partners.
- **Quantity of students from diverse countries working together in the CLF:** The goal is to promote international collaboration by having 80 students from various countries working together within the CLF environment.
- **Creation of a digital twin for the CLF:** This metric measures the development of a digital twin for the CLF, enhancing its virtual representation and operational capabilities.
- **The establishment of pilot training courses:** The objective is to introduce 10 pilot training courses, tailored to meet the specific needs of learners and industry demands.
- **Implementation of collaborative courses between students from different countries:** This metric aims to facilitate cross-cultural exchange and learning by offering 5 collaborative courses involving students from different countries.
- **Establishment of pilot training courses tailored for workers:** This metric focuses on providing specialized training opportunities for workers, with the goal of establishing 10 pilot training courses tailored to their needs.
- **Level of satisfaction among Advanced Manufacturing VET/HVET students:** This metric evaluates the satisfaction levels of VET/HVET students enrolled in Advanced Manufacturing programs, aiming for a satisfaction rate of 80% based on survey responses.

By tracking these metrics, we can assess the effectiveness and impact of our CLF in achieving its objectives, promoting collaboration, and meeting the needs of learners and industry stakeholders.

3.8. COLLABORATION

Collaboration among VET organizations is fundamental to the LCAMP project, and the CLF serves as a catalyst for international cooperation, engaging both educators and learners across various dimensions.

The CLF facilitates collaborative activities throughout different stages of the value chain and for various types of participants. During the implementation phase, researchers and teachers from the consortium partners collaborate to establish the CLF. Once operational, a wider range of users, including VET centres from both the LCAMP consortium and alliance, gain access to its resources and facilities.

Key beneficiaries and users of the CLF include VET centres directly involved in the LCAMP consortium and those from the LCAMP Alliance. These centres play crucial roles in the creation and utilization of the CLF.

Four levels of collaboration are established within the CLF framework:

- **Robot production:** VET students from different countries and regions engage in coordinated tasks such as information sharing, joint projects, competitions, and challenge-based learning, all embedded within the production of robots.

- **CLF course** creation: The cooperative nature of the CLF enables the offering of joint courses for international or regional audiences. These courses, delivered through various mediums including face-to-face, online, and blended learning, are relatively short in duration and tailored to the needs of target audiences.
- **Virtual CLF:** The digital infrastructure allows users to connect virtually, accessing its features remotely. This extends to members of both the LCAMP consortium and alliance, ensuring accessibility even for those without CLF equipment at their local VET schools.
- **Student and staff mobility**: Direct interaction and collaboration among international learners and workers are emphasized, providing valuable opportunities for cross-cultural exchange and skill development.

Furthermore, LCAMP's Open Innovation Community offers additional avenues for interaction among VET centres, fostering a culture of open collaboration and innovation within the project.

4. ADMA – CLF INTEGRATION

The objective of the ADMA methodology is to drive digital transformation within SMEs, facilitated by a comprehensive framework comprising 7 dimensions. In parallel, the CLF represents a digitally enhanced production setting primarily for educational purposes. Its framework delineates the attributes of the CLF and the structure of the LF itself.

While a direct comparison between the two models may not be fully feasible due to their distinct aims, ADMA targets SMEs within established competitiveness and profitability parameters, whereas the CLF focuses on enhancing individuals' competencies and skills. It is noteworthy that the CLF endeavours to emulate the features of actual production companies by incorporating as many elements as possible from such environments. Thus, it appears reasonable to endeavour to characterize the CLF within the context of the ADMA framework, a task elaborated upon in the subsequent discourse.

4.1. SCOPE OF THE FRAMEWORKS

The ADMA framework focuses on the degree of digitisation of SMEs, both as organisations and in their operations, or more specifically on its degree of digital and green transformation. It can be said that the ADMA model is applied to existing production structures. To do so, ADMA analyses 7 dimensions within the companies.

1. Advanced Manufacturing Technologies
2. Digital Factory
3. ECO Factory
4. End-to-end Customer Focussed Engineering
5. Human Centred Organisation
6. Smart Manufacturing
7. Value Chain Oriented Open Factory

Concerning the LCAMP's CLF framework, it describes the features using 8 dimensions.

1. Operational model
2. Purpose and target
3. Process
4. Settings
5. Product
6. Didactics
7. Metrics
8. Collaboration

In this case, the CLF have 2 main aims, firstly to support the creation of new Learning Factory (LF) settings and, secondly, to be able to compare the LF already in place, describing its characteristics and ways of working in the same way.

Aware of the differences, there are very interesting meeting points between the two frameworks.

In the figure 6 the connections between dimensions of both frameworks are shown.

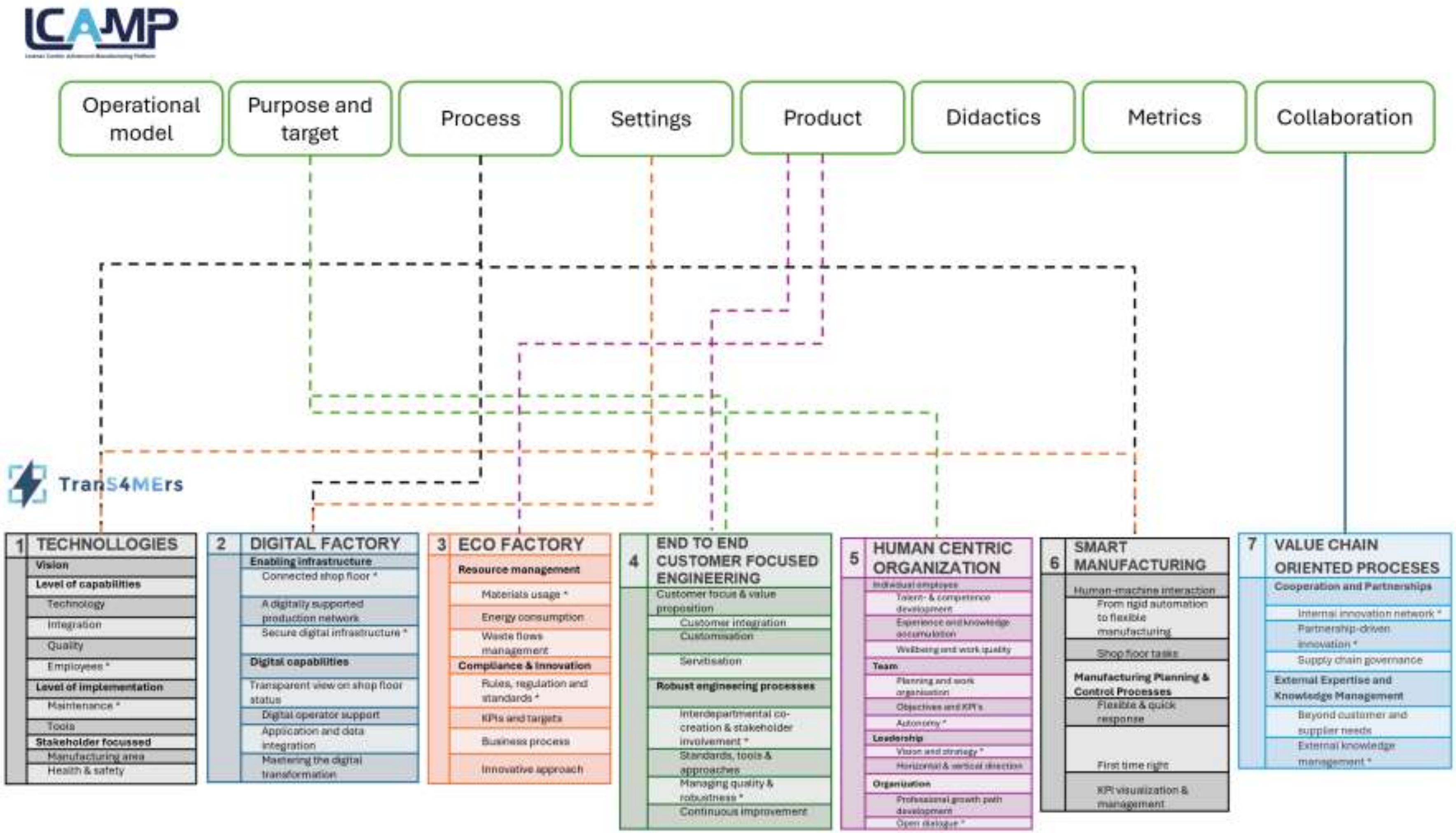

Figure 6: Connections between LCAMP's CLF framework and ADMA framework.

4.2. CONNECTIONS BETWEEN FRAMEWORKS

In the subsequent text, the connections between the two frameworks are outlined. The method for bridging the frameworks involves selecting one as a baseline and assessing the degree to which elements from the second framework adhere to it. This methodology is implemented within the CLF framework, where the dimensions of the ADMA framework are incorporated.

Being the ADMA methodology an incremental procedure to support SMEs, a similar maturity model can be applied to transform LFs to higher level of digitalisation.

The CLF framework is built upon the dimensions proposed by the International Learning Factory Association (IALF), therefore the description tables proposed by them are used to contrast ADMA framework and CLF framework.

4.2.1. OPERATIONAL MODEL AND PURPOSE OF THE CLF

It is important to note that not all dimensions of the CLF framework align easily with those of ADMA. The first two dimensions of CLF, namely clf#1 operational model and clf#2 purpose and target, describe strategic aspects that significantly influence the approach, design, and functions of a specific LF. These dimensions are crucial for contextualizing LFs. Decisions regarding them typically stem from the strategic goals of the organization implementing the LF. For example, choices regarding operational models or financing models are internal decisions of each organization. Despite being essential characteristics of LFs, they are not evaluative parameters within a maturity model. Therefore, there is not a direct correlation between the ADMA framework and the CLF framework concerning these two dimensions.

Table 1: Elements included in the lf#1operational model

<table>
<tr><td rowspan="2">1.1</td><td rowspan="2">operator</td><td colspan="3">academic institution</td><td colspan="5">non-academic institution</td><td colspan="2">profit-oriented operator</td></tr>
<tr><td>university</td><td>college</td><td>BA</td><td>vocational school / high school</td><td>chamber</td><td>union</td><td>employ-ers' asso-ciation</td><td>indus-trial network</td><td>consulting</td><td>producing company</td></tr>
<tr><td>1.2</td><td>trainer</td><td colspan="2">professor</td><td colspan="2">researcher</td><td colspan="2">student assistant</td><td colspan="2">technical expert / int. specialist</td><td>consultant</td><td>education-alist</td></tr>
<tr><td>1.3</td><td>develop-ment</td><td colspan="3">own development</td><td colspan="4">external assisted development</td><td colspan="3">external development</td></tr>
<tr><td>1.4</td><td>initial funding</td><td colspan="3">internal funds</td><td colspan="4">public funds</td><td colspan="3">company funds</td></tr>
<tr><td>1.5</td><td>ongoing funding</td><td colspan="3">internal funds</td><td colspan="4">public funds</td><td colspan="3">company funds</td></tr>
<tr><td>1.6</td><td>funding continuity</td><td colspan="3">short term funding (e.g. single events)</td><td colspan="4">mid term funding (projects and programs < 3 years)</td><td colspan="3">long term funding (projects and programs > 3 years)</td></tr>
<tr><td rowspan="2">1.7</td><td rowspan="2">business model for trainings</td><td colspan="5">open models</td><td colspan="5" rowspan="2">closed models (training program only for single company)</td></tr>
<tr><td colspan="2">club model</td><td colspan="3">course fees</td></tr>
</table>

Table 2: Elements included in the lf#2 purpose and targets

<table>
<tr><td>2.1</td><td>main purpose</td><td>education</td><td>vocational training</td><td>research</td></tr>
<tr><td>2.2</td><td>secondary purpose</td><td>test environment / pilot environment</td><td>industrial production</td><td>innovation transfer</td><td>advertisement for production</td></tr>
<tr><td rowspan="3">2.3</td><td rowspan="3">target groups for education & training</td><td rowspan="3">pupils</td><td colspan="3">students</td><td colspan="7">employees</td><td rowspan="3">entrepreneurs</td><td rowspan="3">freelancer</td><td rowspan="3">unemployed</td><td rowspan="3">open public</td></tr>
<tr><td rowspan="2">bachelor</td><td rowspan="2">master</td><td rowspan="2">phd students</td><td rowspan="2">apprentices</td><td rowspan="2">skilled workers</td><td rowspan="2">semi-skilled worker</td><td rowspan="2">unskilled</td><td colspan="3">managers</td></tr>
<tr><td>lower mgmt</td><td>middle mgmt</td><td>top mgmt</td></tr>
<tr><td>2.4</td><td>group con-stellation</td><td>homogenous</td><td>heterogenous
(Knowledge level, hierarchy, students+employees, etc.)</td></tr>
<tr><td rowspan="2">2.5</td><td rowspan="2">targeted industries</td><td>mechanical & plant eng.</td><td>automotive</td><td>logistics</td><td>transpor-tation</td><td>FMCG</td><td>aerospace</td></tr>
<tr><td>chemical industry</td><td>electronics</td><td>construction</td><td>insurance / banking</td><td>textile industry</td><td>…</td></tr>
<tr><td>2.6</td><td>subject-rel. learning contents</td><td>prod. mgmt & org.</td><td>resource efficiency</td><td>lean mgmt</td><td>auto-mation</td><td>CPPS</td><td>work system design</td><td>HMI</td><td>design</td><td>Intralogistics design & mgmt</td><td>…</td></tr>
<tr><td>2.7</td><td>role of LF for research</td><td>research object</td><td>research enabler</td></tr>
<tr><td>2.8</td><td>research topics</td><td>production management & organization</td><td>resource efficiency</td><td>lean mgmt.</td><td>auto-mation</td><td>CPPS</td><td>change-ability</td><td>HMI</td><td>didactics</td><td>…</td></tr>
</table>

4.2.2. PROCESS AND SETTINGS OF THE CLF

The processes used in the LF are the core of its value chain. In the morphology of the CLF procedures like *product design, process engineering, manufacturing, supply chain management* are developed within the dimension clf#3 process. Under the umbrella of those procedures the full potential on industry 4.0 can be deployed. The description of how these elements is integrated in the CLF are given in the dimension clf#4 settings.

Table 3: Elements included in the If#3 process

3.1	**product life cycle**	product planning	product development	product design	rapid prototyping	manufacturing	assembly	logistics	service	recycling
3.2	**factory life cycle**	investment planning	factory concept	process planning	ramp-up				main-tenance	recycling
3.3	**order life cycle**	configuration & order	order sequencing	production planning and scheduling					picking, packaging	shipping
3.4	**technology life cycle**	planning	development	Virtual testing					main-tenance	moderni-zation
3.5	**indirect functions**	SCM	sales	purchasing	HR	finance / controlling	QM			
3.6	**material flow**	continuous production	discrete production							
3.7	**process type**	mass production	serial production	small series production	one-off production					
3.8	**manufact. organization**	fixed-site manufacturing	work bench manufacturing	workshop manufacturing	flow production					
3.9	**degree of automation**	manual	partly automated / hybrid automation	fully automated						
3.10	**manufact. methods**	cutting	trad. primary shaping	additive manufact.	forming	joining	coating	change material properties		
3.11	**manufact. technology**	physical	chemical	biological						

Table 4: Elements included in the If#4 settings

4.1	**learning environment**	purely physical (planning + execution)	physical LF supported by digital factory (see line "IT-Integration")	physical value stream of LF extended virtually	purely virtual (planning + execution)	
4.2	**environment scale**	scaled down	life-size			
4.3	**work system levels**	work place	work system	factory	network	
4.4	**enablers for changeability**	mobility	modularity	compatibility	scaleability	universality
4.5	**changeability dimensions**	layout & logistics	product features	product design	technology	product quantities
4.6	**IT-integration**	IT before SOP (CAD, CAM, simulation)	IT after SOP (PPS, ERP, MES)	IT after production (CRM, PLM…)		

In this sense, taking the dimension of ADMA framework, 5 of those are useful to evaluate the maturity of the processes and to give light to further improvements: ADMA#1 Advanced Manufacturing Technologies, ADMA#2 Digital Factory, ADMA#3 Eco Factory, ADMA#5 Human Centred Organisation and ADMA#6 Smart Manufacturing.

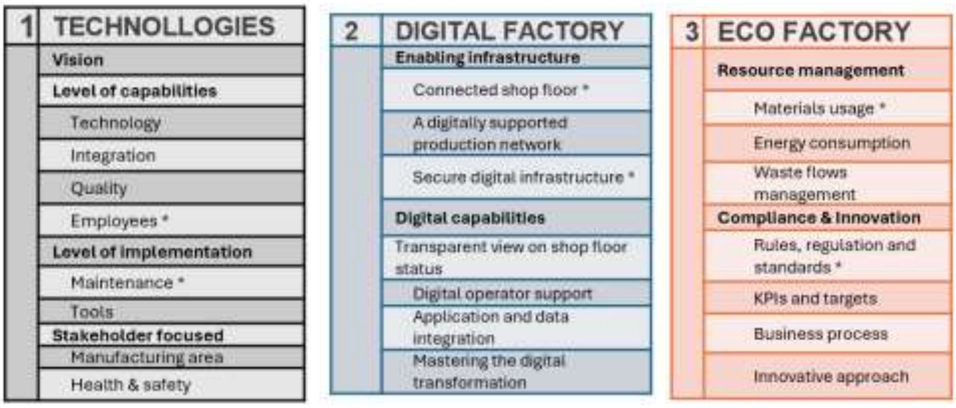

Figure 7: ADMA dimensions #1, #2 and #3

ADMA dimension **ADMA#1 Advanced Manufacturing Technologies,** offers a way to measure to what extent LFs are deploying state-of-the-art manufacturing devices. This analysis cover not only purely technical aspects but also things like quality assurance and employees' competencies on the referred technologies. When it come to the settings of the LF (clf#4 settings), relevant aspects like paces, maintenance, health and security can be measured using this ADMA dimension.

Crossing **ADMA#2 Digital Factory** with clf#3 process and clf#4 settings, aspects related to the digital layer implemented in the CLF can be measured. Connectivity, cybersecurity, digital workstations, data integration and other aspects can be assessed.

Within this dimension to measure the level of capabilities aspects such the following are analysed:

- The level of usage of Infrastructure IT/OT, including solutions such: PLM (Product Lifecycle Management), APS (Advanced Planning and Scheduling): GMAO ó CMMS (Computerized Maintenance Management System), MRP (Material Requirements Planning), ERP (Enterprise Resource Planning), CIM (Computer Integrated Manufacturing).
- The level of machines connected to a network that allows data exchange and the solutions used to that purpose: SCADA (Supervisory Control and Data Acquisition), HMI (Human machine interaction), MES (Manufacturing Execution System).
- The use of specific software for the management of the different processes and areas of the company including supplier and customer relationship management such: CRM (Customer Relationship Management), CMS (Content Management System), SCM (Supply Chain Management), WMS (Warehouse Management System), PIM (Product Information Management), HCM (Human Capital Management).
- Cybersecurity, overall (cyber) security status of each device, access point, and the overall digital infrastructure.

By using the **ADMA#3 Eco Factory,** many aspects related with ecological sustainability are considered. From eco design, product life management, waste materials, energy consumptions and efficiency and other aspects can be considered. Interestingly, the use of respective KPIs is taken into account.

Figure 8: ADMA dimension #5

ADMA#4 Human Centred Organisation dimension is not straightforward applicable to CLFs due to the lack of actual employees producing components. However, this dimension brings very interesting elements that can be considered among users of the LF, normally students. Practices towards human centricity need to be included in the LF and the organizational aspects that allow these practices to happen can be considered an assessed under this dimension. Those elements should be included both in the clf#3 process and clf#4 settings dimensions.

Within the human centric aspects, the following elements are measured in the ADMA framework:

- Existence of functional organisation chart with roles and responsibilities defined and implemented in the company.
- Existence of procedures in place to evaluate the current tasks and responsibilities of each position and their performance and identify changes needed to improve the efficiency and productivity of these.
- Existence of channels of communication established to ensure that all employees understand their tasks and responsibilities.
- Employees training strategy in place.
- Employees motivation analysis.
- Regular performance evaluations of competencies and achievement of objectives of managers and key personnel in the company.

There are also some strategic elements considered. Some examples are:

- The used company strategy: diversification strategy, cost strategy, differentiation strategy, focus strategy.
- Existence of corporate social responsibility policies, adopting ethical and sustainable practices to improve the company's image and contribute to the community.
- Existence of diversity and inclusion policies.
- Existence of innovation policies.

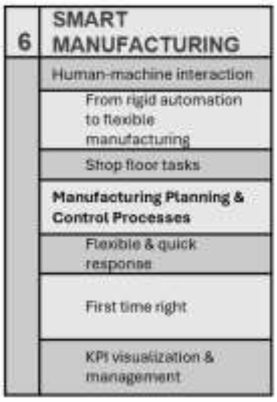

Figure 9: ADMA dimension #6

Finally, the elements covered by the **ADMA#6 Smart Manufacturing** dimension also affect directly the LFs. Although this direction also requires a production system, when the LFs are in production mode most of the aspects referred here.

For this dimension, these are some examples of the measured elements:

- The use of specific software for the management of the different processes and areas of the company including supplier and customer relationship management such: CRM (Customer Relationship Management), CMS (Content Management System), SCM (Supply Chain Management), WMS (Warehouse Management System), PIM (Product Information Management), HCM (Human Capital Management).
- Data analysis and exploitation: to what extent production data is analysed with the help of a digital solution/platforms, whether the status of the production equipment is monitored in real time (machine status, working reference, number of pieces or progress of the process, etc.).
- Ability to analyse and exploit maintenance data.
- Automation, to what extent workshop equipment allow for autonomous and unattended operations.

4.2.3. PRODUCT

The product or range of products selected for the LF conditionate several aspects of its implementation, that is the reason it deserves an independent dimension in the CLF framework. The repercussions that the product choice has on other dimension such process or setting concerning the digital maturity of the CLF is included in the previous section. However, the technology embedded in the product itself and ecological aspects related to the product deserve a separate analysis.

Table 5: Elements included in the lf#5 product

5.1	**materiality**	material (physical product)	immaterial (service)				
5.2	**form of product**	general cargo	bulk cargo				
5.3	**product origin**	own development	development by participants	external development			
5.4	**marketability of product**	available on the market	available on the market but didactically simplified	functional, could be available on the market	without function/ application, for demonstration only		
5.5	**no. of differ-ent products**	1 product	2 products	3-4 products	> 4 products	flexible, developed by participants	acceptance of real orders
5.6	**no. of variants**	1 variant	2-4 variants	4-20 variants	...	flexible, depending on participants	determined by real orders
5.7	**no. of components**	1 comp.	2-5 comp.	6-20 comp.	21-50 comp.	51-100 comp.	> 100 comp.
5.8	**further product use**	re-use / re-cycling	exhibition / display	give-away	sale	disposal	

The assessment of the maturity level of the dimension clf#5 product could be carried out using **ADMA#1 Advanced Manufacturing Technologies** and **ADMA#3 Eco Factory**.

Figure 10: ADMA dimensions #1 & #3

It is observable that not all the element included in these two ADMA dimensions are straightforward useable for the CLF product assessments. Some adaptation would be needed. We would be referring to product's technologies and eco-products.

4.2.4. DIDACTICS AND METRICS

The dimensions clf#6 didactics and clf#7 metrics from the LCAMP framework describe elements rather specific for educational environments. The didactics refers to aspects relevant for the teaching and learning process whereas the metrics propose KPIs to measure many of those.

ADMA frameworks do not deal with such elements as they do not normally appear in SMEs. These two dimensions have not counterparts in ADMA framework.

Table 6: Elements included in the lf#6 didactics

6.1	**competence classes**	technical and methodological compentencies	social & communication competencies	personal competencies	activity and implementation oriented competencies		
6.2	**dimensions learn. targets**	cognitive	affective	psycho-motorical			
6.3	**learn. scenario strategy**	instruction	demonstration	closed scenario	open scenario		
6.4	**type of learn. environment**	greenfield (development of factory environment)	brownfield (improvement of existing factory environment)				
6.5	**communication channel**	onsite learning (in the factory environment)	remote connection (to the factory environment)				
6.6	**degree of autonomy**	instructed	self-guided/ self-regulated	self-determined/ Self-organized			
6.7	**role of the trainer**	presenter	moderator	coach	instructor		
6.8	**type of training**	tutorial	practical lab course	seminar	workshop	project work	
6.9	**standardization of trainings**	standardized trainings	customized trainings				
6.10	**theoretical foundation**	prerequisite	in advance (en bloc)	alternating with practical parts	based on demand	afterwards	
6.11	**evaluation levels**	feedback of participants	learning of participants	transfer to the real factory	economic impact of trainings	return on trainings / ROI	
6.12	**learning success evaluation**	knowledge test (written)	knowledge test (oral)	written report	oral presentation	practical exam	none

Table 7: Elements included in the If#7 metrics

7.1	**no. of participants per training**	1-5 participants	5-10 participants	10-15 participants	15-30 participants	>30 participants	
7.2	**no. of standardized trainings**	1 training	2-4 trainings	5-10 trainings	> 10 trainings		
7.3	**aver. duration of a single training**	< 1 day	1-2 days	3-5 days	5-10 days	10-20 days	> 20 days
7.4	**participants per year**	< 50 participants	50-200 participants	201-500 participants	501-1000 participants	> 1000 participants	
7.5	**capacity utilization**	< 10%	10 – 20%	21 – 50 %	51 – 75 %	76 – 100 %	
7.6	**size of LF**	< 100 sqm	100 – 300 sqm	300-500 sqm	500-1000 sqm	> 1000 sqm	
7.7	**FTE in LF**	< 1	2-4	5-9	10-15	> 15	

4.2.5. COLLABORATION

One of the singularities of the CLF comparing with other stablished LFs is the vocation for collaboration behind the approach. The CLF aims to boost collaboration among partners from different regions in EU and therefore the seek for collaboration opportunities is a mantra.

The tools to support this collaboration are integrated in the dimension clf#8collaboration and it finds a direct counterpart in the dimension **ADMA#7 Value Chain Oriented Open Factory** from the ADMA framework.

Figure 11: ADMA dimension #7

This ADMA dimension allows to assess the quality of the collaboration mechanisms in place. It also gives insight on how to move forward to improve the collaboration mechanisms.

4.3. DEVELOPMENT OF THE CLF BASED ON THE ADMA FRAMEWORK

It has been observed that there is potential for integrating the ADMA dimensions within the CLF framework, as the elements of the ADMA dimensions can enhance and complement the existing framework. Therefore, exploring the possibility of transferring elements between the two frameworks is valuable.

The ADMA framework outlines a step-by-step approach for transitions in SMEs. Currently, the CLF framework is static, describing the existing LFs. By incorporating insights from ADMA, a maturity model can be applied to evolve the LFs. This maturity model would primarily address the process and settings dimensions.

As part of WP6 tasks, LCAMP endeavours to develop a Self-Assessment Tool (SAT) for LF implementation. This deliverable will assist VET centres in integrating LFs into their operations. The approach discussed here is highly applicable to the development of such a tool.

Additionally, enhancements to the CLF framework will be incorporated into deliverable D6-1_Part 3-Guidelines for the implementation of i4.0 technologies in VET labs, scheduled for December 2024. This document will include definitions of maturity steps towards technology implementation, aligning with the evolving needs of the field.

5. CONCLUSIONS

There are many ideas that can be highlighted after the analysis and connection of both models, the ADMA methodology used to support SMEs in their digital transformation journey and the CLF concept that allows the analyses of VET centres through its 8 dimensions. We would like to highlight six main conclusions:

1. **Significance of ADMA Methodology for SMEs' Digital Transformation**: The ADMA methodology plays a crucial role in supporting SMEs throughout their digital transformation journey. Its structured approach provides SMEs with a roadmap for embracing technological innovation, thereby enhancing their competitiveness and sustainability in the digital economy.
2. **Utility of CLF dimensions to describe the set-ups of LFs at Vocational Training Centres**: The CLF concept offers a valuable framework for analysing and enhancing technical labs at vocational training centres. By evaluating eight dimensions CLFs enable a comprehensive assessment of the features of the LFs and facilitate the integration of Advanced Manufacturing technologies into VET curricula.
3. **Integration of ADMA Dimension into CLF Framework**: The potential for integrating the ADMA dimension within the CLF framework has been identified, offering an opportunity to enhance and complement the existing framework. Exploring the transfer of elements between these two frameworks is valuable, as it can lead to a more comprehensive and dynamic approach to educational excellence.
4. **Evolution of CLF through ADMA Insights**: The ADMA framework provides a structured approach for transitions in SMEs, presenting a step-by-step methodology. In contrast, the CLF framework, as it stands, is static, primarily describing existing Learning Factories (LFs). Incorporating insights from ADMA enables the application of a maturity model to evolve the LFs, particularly addressing the process and settings dimensions.
5. **Development of Self-Assessment Tool (SAT) for LF Implementation**: Efforts are underway to develop a Self-Assessment Tool (SAT) for LF implementation, aiding VET centres in integrating LFs into their operations. The approach discussed in this study aligns well with the development of such a tool, offering practical guidance and insights for effective LF implementation.
6. **Enhancement of CLF Framework**: LCAMP project will provide guidelines for the implementation of Industry 4.0 technologies in VET labs to enhance the CLF framework. This will include definitions of maturity steps towards technology implementation. These enhancements aim to meet the evolving needs of the field, ensuring that VET centres remain at the forefront of educational innovation.

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Co-funded by
the European Union

Funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or the European Education and Culture Executive Agency (EACEA). Neither the European Union nor EACEA can be held responsible for them.