INDUSTRY-ACADEMIA FORUM
TO UNCOVER THE POTENTIAL OF
EMERGING ENABLING TECHNOLOGIES

CO-CREATION WORKSHOP PRELIMINARY RESULTS

Novel Enabling Technologies for a Sustainable Future: Real-time Based Digital Twins & Simulation Technologies

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Group 1: George Michalos, Gilberto Burgio, Henrikki Salo-Pöntinen, Matteo Palpacelli, Pol Aixas Martinez, Pol Torrent Torros, Xinyi Tu

Use-case: HATOM – **H**uman-**A**ware Digital **T**wins for Complex **O**perational **M**anagement

Facilitators: Francesca Foliti (APRE), Sofi Kurki (VTT)

Given the diverse areas of expertise within the group, participants decided to tackle a cross-cutting challenge that affects different sectors: efficient and sustainable management of complex operational processes and systems. A series of issues were discussed, generally leading to systemic inefficiency, resource waste, and poor transparency and traceability in complex working environments such as airports, factories, and hospitals. Some of the most debated issues were the lack of structured databases, the need for different knowledge management processes (both at the operational stage and at the R&D stage), and the difficulty of tracking workflows thoroughly.

Then, the group started building up a general and adaptable solution to enhance better decision-making, knowledge gathering and elicitation, and ecosystem collaboration in complex workplaces. They ultimately envisaged that Cognitive Digital Twins could help combine tacit knowledge (human knowledge) with sensor-based and data-driven knowledge, by providing a simplified reflection of the real system and ultimately enabling and facilitating the inclusion of the human element in the realm of digital twins. The added value of this solution lies in the fact that it provides managers and decision-makers with a new understanding of complex operational systems *and* with an easily attainable, dynamic visualization of the system itself. Not only does the solution increase efficiency and sustainability, but it also has potential to reduce process costs, to enhance accountability and transparency, as well as to "humanize" complex systems' digital twins by including information both from the physical and the human environments.

In this framework, cognitive digital twins represent an enabling technology to build the necessary digital infrastructure and to regulate information flows. Additional key resources for the development of the proposed solution include reality measurement systems (e.g., sensors, questionnaires, data...), AI support, wide data centres availability, and compatible, interoperable devices and systems.

As for the main feasibility limits, the proposed solution is quite demanding in terms of data maintenance, energy consumption, and better regulation. Moreover, it poses several challenges when it comes to sensitive data protection and social acceptance of "surveillance" mechanisms. At the same time, many benefits were mentioned: human and financial capital retention and valorisation, improved working conditions, and increased inclusivity in the workplace.

Group 2: Jose Arco Martín de Rosales, Luca Carbonari, Fabio Della Valle, Pradeep Kundu, Marie Pezzillo, Elisa Prati, Marisol Rojas

Use-case: BRIDE – **B**attery **R**ecycling **I**nnovation through **D**igital-twins re-**E**ngineering

Facilitators: Marina Dias (INL), Viviana Perez Clausen (i2CAT)

Given their broad expertise, participants initially focused on a common challenge for SMEs: integrating robotics into manufacturing, particularly in retrofitting processes for better efficiency. The exercise began with mapping out problems and solutions, identifying high costs, regulatory compliance, and digital gaps as key hurdles. These issues are linked to the need for remaining competitive and sustainable in an environment marked by skilled labour shortages and lack of trust towards new technologies. Proposed solutions emphasize human-centric approaches, enhanced training, operational guidelines, and the development of a unified EU digital framework. Addressing these challenges requires fostering a culture of digitalization, reskilling workers, and providing robust technical and financial support to implement effective robotics solutions.

In the next phase, the group focused on a specific energy-related sub-sector that relies heavily on manual labour in harsh environments: battery recycling, with the goal of material recovery. The primary challenge identified was the availability of battery information to enable efficient robotic disassembly. The proposed solution involves using data from the battery's digital passport and predictive maintenance to ascertain the battery's end-of-life. This data, combined with worker expertise incorporated into Cognitive Digital Twins, would help train robots to improve the disassembly process, enhancing the process's specificity based on different battery components. This human-machine collaboration aims to improve material circularity in batteries, thus enhancing the sustainability of the energy sector and ensuring safer working conditions. Key stakeholders include battery manufacturers, the recycling industry, researchers, ethics specialists, policymakers, users (like the automotive and stationary sectors), and ultimately, the public. The success of this solution hinges critically on continuous investment in research and innovation, workforce training, and the integration of social sciences and humanities experts to address potential ethical and legal challenges. The availability of battery data, along with concerns about privacy and safety, including worker safety, could limit the implementation of this solution

The final use-case is "BRIDE – Battery Recycling Innovation through Digital-twins re-Engineering". It focuses on the efficient reuse of battery materials and it involves re-skilling and up-skilling the workforce, addressing acceptance and trust in digital technologies. The core of the solution introduces new robotics into complex industrial processes, with robots trained based on worker expertise and battery data required to disassemble batteries. The implementation in real environments is anticipated within 5-8 years, targeting the recycling and battery industries. This solution is expected to create safer working conditions, reduce Europe's dependency on imported critical raw materials, lower the carbon footprint, and protect natural ecosystems. However, uncertainties remain regarding potential new pollutants and the energy demands of these new assisted processes. The long-term social impact includes the sovereignty of European industry and the potential application of retrofitting solutions across various sectors.

Group 3: Alexandru Roja, Carlos Molina, Gianfranco Modoni, Katri Salminen, Roberto Venditti, Samia Chelbi

Use-case: TWIN2WIN

Facilitators: Brigita Jurisic (INL), Marta Martorell Camps (i2CAT)

The group directed their efforts on the automotive sector, specifically addressing the needs of engine assembly workers. Participants identified key challenges in training and supporting workers with diverse skills, abilities, and experience levels. The central problem was the lack of personalized, adaptive training systems to accommodate workers with varying characteristics, including those with disabilities or age-related impairments.

The proposed solution, named TWIN2WIN, leverages Cognitive Digital Twins to create a hyper-personalized training system. This system adapts to individual needs by simulating realistic scenarios through extended reality (XR) technologies, including virtual and mixed reality. Workers interact with a digital twin of an engine, receiving customized guidance tailored to their skill level and experience. For example, novice workers receive step-by-step instructions, while experienced workers see only critical updates or new information. The system supports both on-site and remote interactions, enabling flexible training and reducing the need for physical resources. The solution emphasizes a collaborative and inclusive workspace, with workers and technology (such as robots) interacting dynamically. The use of sensors and factory telemetry ensures real-time data collection, which feeds into the digital twin for continuous adaptation and improvement. Augmented semantic features link virtual models to real-world applications, fostering an intelligent decision-making process. This iterative feedback loop enhances worker training and performance over time.

Participants highlighted the potential benefits of TWIN2WIN. Socially, the system improves inclusivity, allowing a more diverse workforce to thrive, including individuals with disabilities or age-related challenges. It fosters motivation, supports knowledge transfer, and empowers workers by providing accessible and effective training. Environmentally, the reliance on digital twins minimizes waste by reducing the need for physical prototypes or excessive resource consumption during training. The broader impact of TWIN2WIN extends beyond the factory floor. The system's scalability allows it to be adapted for academia, schools, and other industries, enabling students and trainees to gain hands-on experience through simulations. This approach promotes a paradigm shift in manufacturing, fostering more inclusive, efficient, and environmentally sustainable practices.

In summary, TWIN2WIN represents an innovative application of cognitive digital twins in the automotive sector. It creates a personalized, human-centered training system that addresses diverse workforce needs, enhances productivity, and supports sustainable development, positioning it as a transformative solution for modern manufacturing challenges.

Group 4: Ensieh Iranmehr, Greg Agriopoulos, Jordi Picas, Micaela Morettini, Pablo Orons Vazquez, Patrizio Pelliccione

Use-case: PrevenTwin for WorCares

Facilitator: Livia Di Bernardini (APRE)

The group focused on the industrial environment, identifying poor working conditions as a critical issue affecting workers. The main problem identified was the lack of real-time monitoring and predictive tools in workplaces, which may lead to increased injuries, absenteeism, and significant economic costs. The root causes of these challenges were attributed to limited access to advanced safety training, inadequate technological resources, and a lack of systematic data-driven approaches to safety. The visible effects included an increase in workplace hazards, reduced productivity, and diminished morale among workers.

To address these challenges, the group proposed a solution that leverages emerging technologies, specifically Cognitive Digital Twins. These tools would enable real-time monitoring and predictive analysis of workplace risks by simulating environmental conditions and worker behavior. This solution was designed to meet the critical needs of real-time data collection, advanced analytical capabilities, and user-friendly tools for both workers and managers. The expected outcomes included a significant reduction in workplace accidents, improved safety, and enhanced worker morale, ultimately fostering a safer working environment.

The participants refined further the problem and solution, identifying specific challenges in implementing predictive technologies within dynamic workplace environments. The Cognitive Digital Twins were positioned as a core technological enabler, offering capabilities to simulate various scenarios, analyze real-time data, and provide actionable insights to prevent risks. The key stakeholders involved were identified as workers, safety officers, technology providers, and workplace managers, each playing a critical role in implementing and benefiting from the solution. Resources such as access to comprehensive workplace data, technical expertise, and funding were considered essential for success. The group also highlighted potential limitations, including ethical concerns around data privacy, legal and regulatory constraints, and resistance to change from certain stakeholders.

In the final phase, the participants detailed the use-case, giving the solution the name *PrevenTwin for WorCares*. The system would utilize Cognitive Digital Twins to collect and analyze critical workplace data, such as environmental conditions, equipment status, and worker activities. By simulating different scenarios and identifying potential risks, the system could provide real-time recommendations to prevent accidents. The expected benefits were both social and environmental. Socially, the system would enhance workplace safety, reduce injury rates, and foster greater job satisfaction and trust among workers. Environmentally, it would optimize the use of resources, improve machinery and equipment monitoring, and support sustainable operational practices. The overall impact of the solution was envisioned as a transformative improvement in workplace safety, addressing immediate concerns while promoting long-term efficiency and sustainability.