NTNU | Norwegian University of Science and Technology

Introduction to Industry 5.0

Trends, Opportunities, and Challenge

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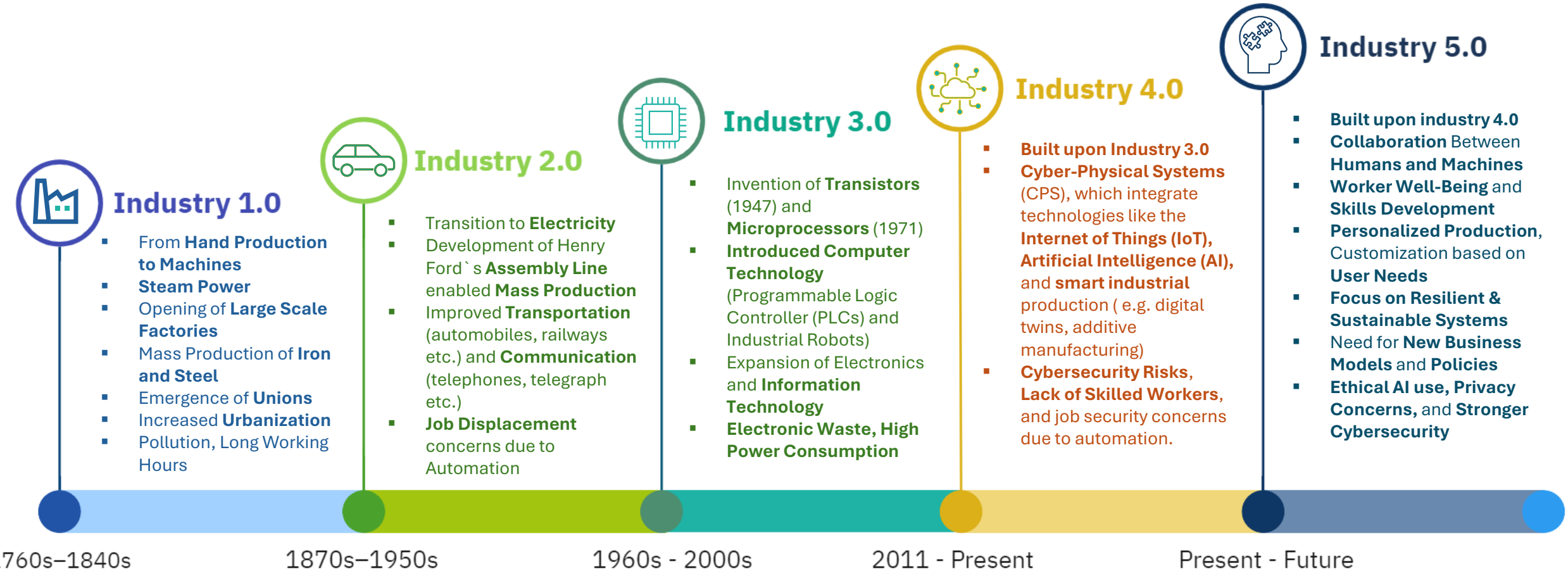
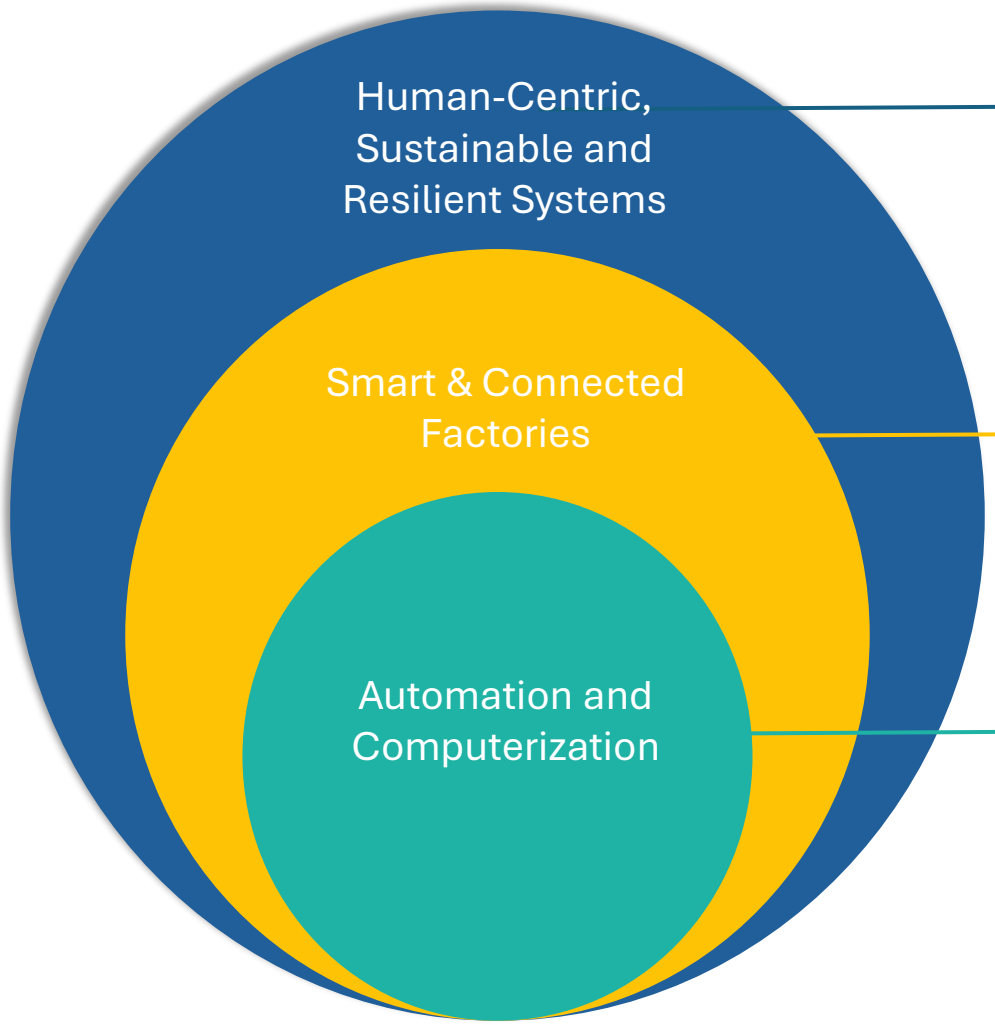
Timeline & Context

Industry 1.0 ⟶ **Industry 5.0**



[5,8]

Digitalization



Industry 5.0

- First Industrial Revolution Led by Human
- Restoring the Missing Link Between Nature and Human Made Ecosystems
- Foundations of Technology + Human Values

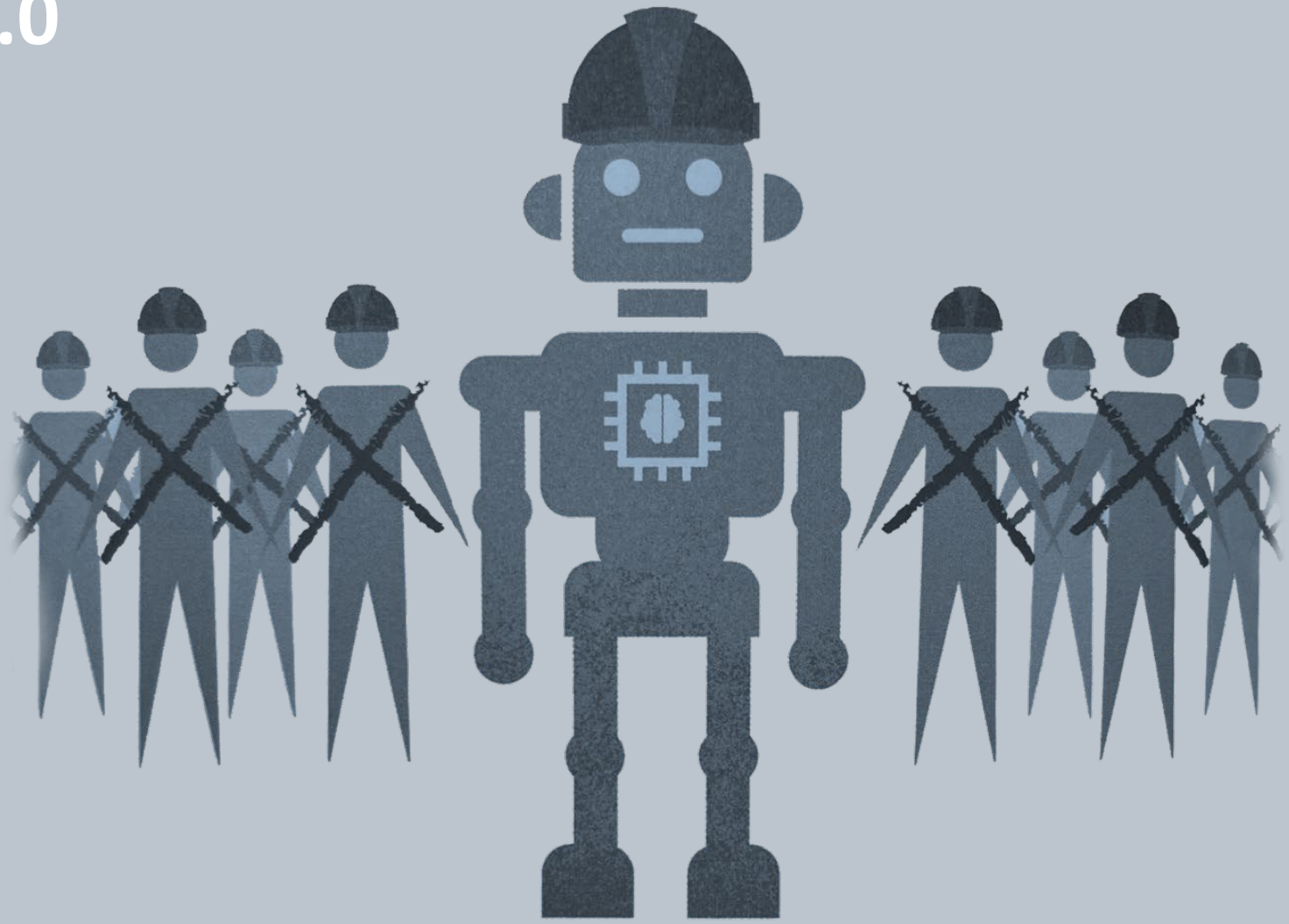
Industry 4.0

- Increased Interconnectivity Among Computers and Machines
- Exchanging Data and Coordinating Actions through the Value Chain

Industry 3.0

- Bell Labs, USA 1947 - Transistors were invented
- First transistors enabled radios and small calculators. Military and Space ambition in USA accelerated rapid transistor innovation.
- Machines and computer-based controls were introduced.

Industry 4.0



Heavily Relies on Automation & Digitalization
Lacks Human Centric Perspective

[11]

Industry 4.0 Toward 5.0 Vision

	Industry 4.0	Industry 5.0
Drivers	economic and technological factors	economic, social, environmental, and ethical considerations
Power Source	Electrical power, Fossil-based fuels, Renewable power sources	Electrical power, renewable power sources
Technology	Automation and data exchange, Artificial Intelligience(AI), Cyber-physical systems, Internet of Things(IoT), Cloud computing, Big Data	Adding on Industry 4.0, AI-Powered collaborative robots, Smart Materials, Digital Twins
Research Focus	Organizational Research, Process Improvement and Innovation, Business Administration	Smart Environments, Organizational Research, Process Improvement and Innovation, Business Administration
Goals	Increased production output, improved quality, lower production costs, faster production times	Enhanced human capabilities, personalized products and services, sustainable and ethical production, societal progress

Industry 5.0 is best seen as an evolution or next step after Industry 4.0. It still relies on the main technologies (IoT, cloud, data analytics, cyber-physical systems, etc.) that define Industry 4.0.

[1,13]

Definitions of Industry 5.0

Industry 5.0 is still evolving, and **various definitions exist from industry practitioners and researchers**.

1. Industry 5.0 is a **human-led industrial evolution based on the 6R principles (Recognize, Reconsider, Realize, Reduce, Reuse, and Recycle)** of industrial upcycling. It is a systematic waste prevention technique and logistics efficiency design to value life, promote innovative creations, and produce high-quality custom products by Michael Rada, Founder of Industry 5.0.

2. Industry 5.0 brings the human workforce back to the factory, where **humans and machines work together to increase process efficiency** by **using human brainpower and creativity**, integrating workflows with intelligent systems.

3. Industry 5.0 integrates the strengths of cyber-physical production systems (CPPS) and human intelligence to create synergetic factories. It also **seeks innovative, ethical, and human-centered design to address the weakening of manpower caused by Industry 4.0.**

4. Industry 5.0 is a **human-centric design solution** where humans and cobots collaborate to enable personalizable autonomous manufacturing through enterprise social networks.

[6] More definitions are mentioned in the article.

Development of Industry 5.0

2015 Industry 5.0 Launch

2020 Named leading industrial trend of a decade

First Industry 5.0 Ambassador Assigned

2021 Integrated into European Union Framework

2023 118 Industry 5.0 ambassadors, 118 countries

2024 United Nations Environment Programme (UNEP) integrated Industry 5.0 into 2024 Outlook

[Michael Rada - https://www.slideshare.net/slideshow/industry-5-0-power-of-industrial-evolution/271750123?from_search=5#1]

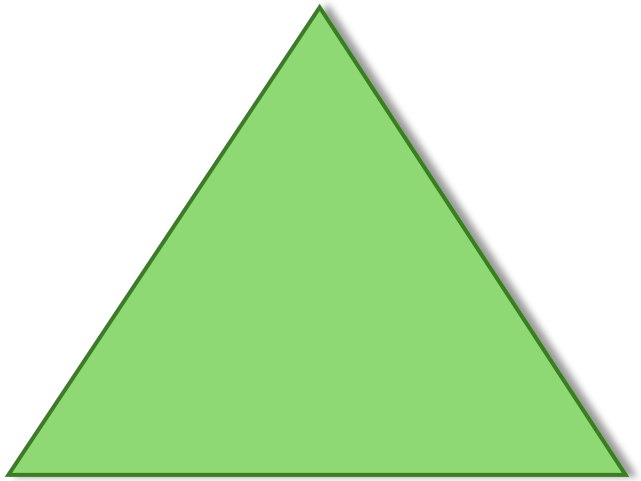
Types of Waste

Depending on the **industrial upcyling** five types of waste is defined.

- **PHYSICAL WASTE:** Trash and items delivered to garbage bins, containers, landfills
- **SOCIAL WASTE:** People limited in their will to make work their living
- **URBAN WASTE:** Buildings, land, locations unused and not utilized properly
- **PROCESS WASTE:** Not efficient processes and no value services
- **WASTING OF TIME:** The only waste which can not be recovered once wasted

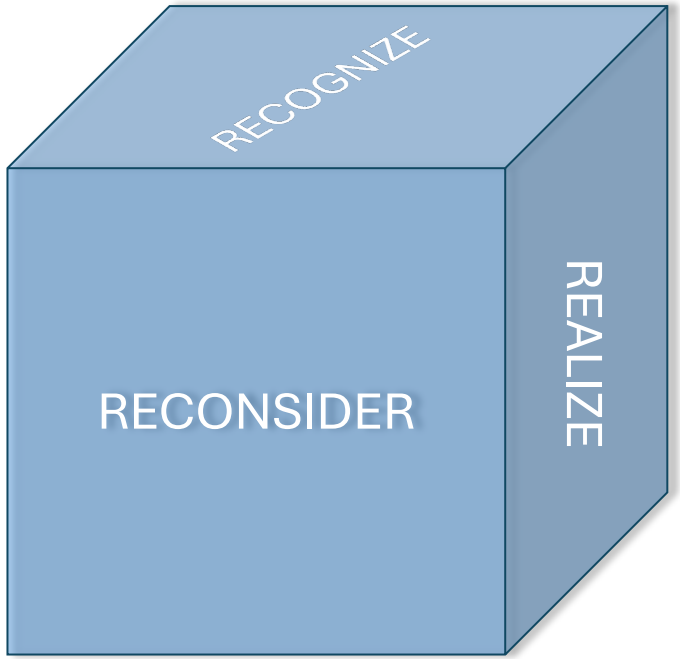
[Michael Rada - https://www.slideshare.net/slideshow/industry-5-0-power-of-industrial-evolution/271750123?from_search=5#1]

Methodology of Systemic Waste Prevention



3R

RECOGNISE
RECONSIDER
REALIZE
REDUCE
REUSE
RECYCLE



6R

[Michael Rada - https://www.slideshare.net/slideshow/industry-5-0-power-of-industrial-evolution/271750123?from_search=5#1]

Do Not Waste

1. RECOGNISE

2. RECONSIDER

3. REALIZE

Can we recognize something must not become waste? Can we reconsider what to do with the item we saved?

If you do right, **you do not need to Reduce, Reuse, Recycle** and pay for never ending waste management

[Michael Rada - https://www.slideshare.net/slideshow/industry-5-0-power-of-industrial-evolution/271750123?from_search=5#1]

EU Framework - Definitions of Industry 5.0 Pillars

Human - Centric

used to describe systems that are designed to work in ways that people can easily understand and learn *(Cambridge Dictionary)*

Refers to a set of principles that prioritize human needs, well-being, and aspirations, guiding the design, development, and deployment of technologies and organizational practices.

Sustainable

Capable of being maintained or continued at a certain rate or level. *(Oxford Dictionary)*

Commitment to find a balance among economic improvement, social equity, and environmental protection, with the aim of helping to achieve the Sustainable Development Goals (SDGs).

Resilient

Capacity to adapt and recover quickly from disruptions or unexpected changes *(Cambridge Dictionary)*

Designing systems, supply chains, and organizations that can maintain essential functions during challenging circumstances while minimizing negative impacts on society and the environment.

Industry 5.0 in EU FRAMEWORK

[1,2,3]

EU Framework - Industry 5.0

- Addressing **Social Inequality** and **Worker Well-being**
- Shifting from Technology-Driven to **Human-Driven Innovation**
- Encouraging **Meaningful and Engaging Work**
- Attracting **and Retaining Talent** in a Changing Labor Market
- Aligning with **European Values and Fundamental Rights**

Human - Centric

- Urgency of **Climate Change** and Resource Scarcity
- Shifting from **Linear** (take-make-waste) to **Circular** Models (production, use, recycle)
- Meeting **Consumer Demands and Expectations**
- Aligning with **EU Policy Priorities**

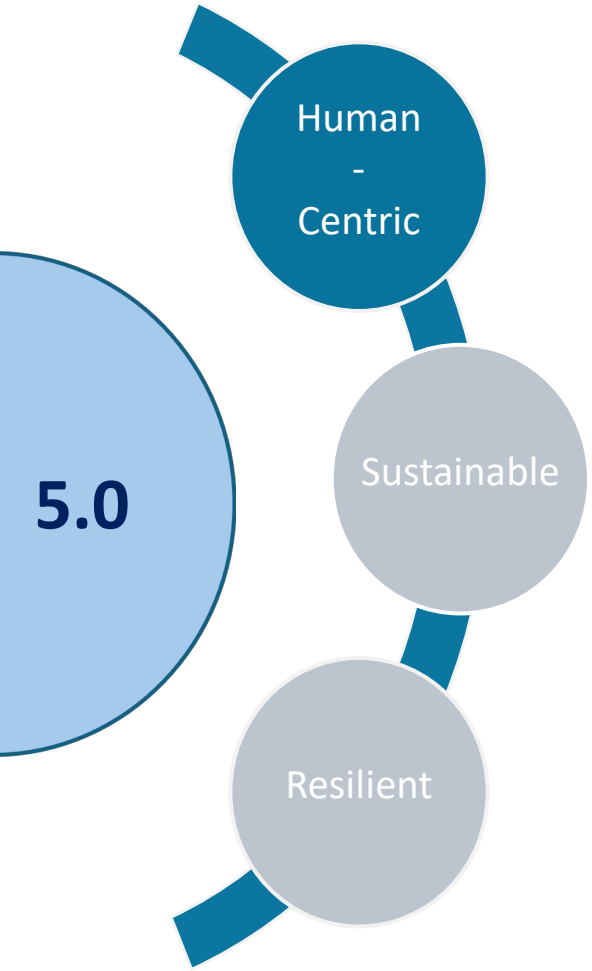
Sustainable

- Lessons from Recent Crises (e.g. Covid 19)
- **Disruptions** in global **supply chains**
- Geopolitical Shifts and **Global Uncertainties**
- Anticipating Future Disruptions

Resilient

[1,2,3]

Industry 5.0 - Human-Centric



Worker Empowerment & Participation

- *Co-Design & Co-Creation:* Engage employees in the development of new technologies and processes.
- *Decision-Making & Autonomy:* Provide staff with genuine input and flexibility in their roles.
- *Continuous Learning & Skill Development:* Commit to ongoing education for emerging technologies.
- *Well-Being & Job Satisfaction*: Enable safe and healthy work environments

Social Inclusion & Diversity

- *Accessibility:* Ensure that technologies and environments accommodate individuals of all abilities.
- *Intergenerational Collaboration:* Encourage knowledge exchange among different age groups.
- *Addressing Bias:* Implement fair and impartial practices and systems within the workplace.

Human - Machine Collaboration

- *Integrated Technologies(e.g Robots, Digital Twins, AI, AR/VR):* Employ various advanced systems that complement and improve human abilities, deliver real-time data, optimize workflows, and keep employees in the decision-making process.

Ethical & Responsible Tech Development

- *Data Privacy & Security:* Protect employee information and prevent its misuse.
- *Transparency & Explainability:* Ensure that technologies are clear and trustworthy.
- *Human Oversight:* Maintain human control over critical decisions and actions.

Used various resources included in the presentation.

Industry 5.0 - Human-Centric

Human Centric Goals

Level	Goals/Effects
Individual/Micro	- Worker empowerment - Higher workers' satisfaction - Fostering creativity - Better work-life balance and well-being - Better security - Life-long learning - Ethical approaches to business
Organisational/Meso	- Growth & productivity - Employee retention & attraction - Enhanced innovation & learning capacities of organisations - Aligning the core beliefs and values of the organisation with behaviours that prioritise people as well as the planet - Flexibility & agility, future-preparedness at organisational level
Economic and societal/Macro	- Long-term competitiveness through enhanced innovation and learning capacity of companies - More labour market resilience, in particular less unemployment and less occupational downgrading due to technological shifts - Emergence of industry 5.0 related learning ecosystems - Improved quality of work and health for workers - Sustainable development

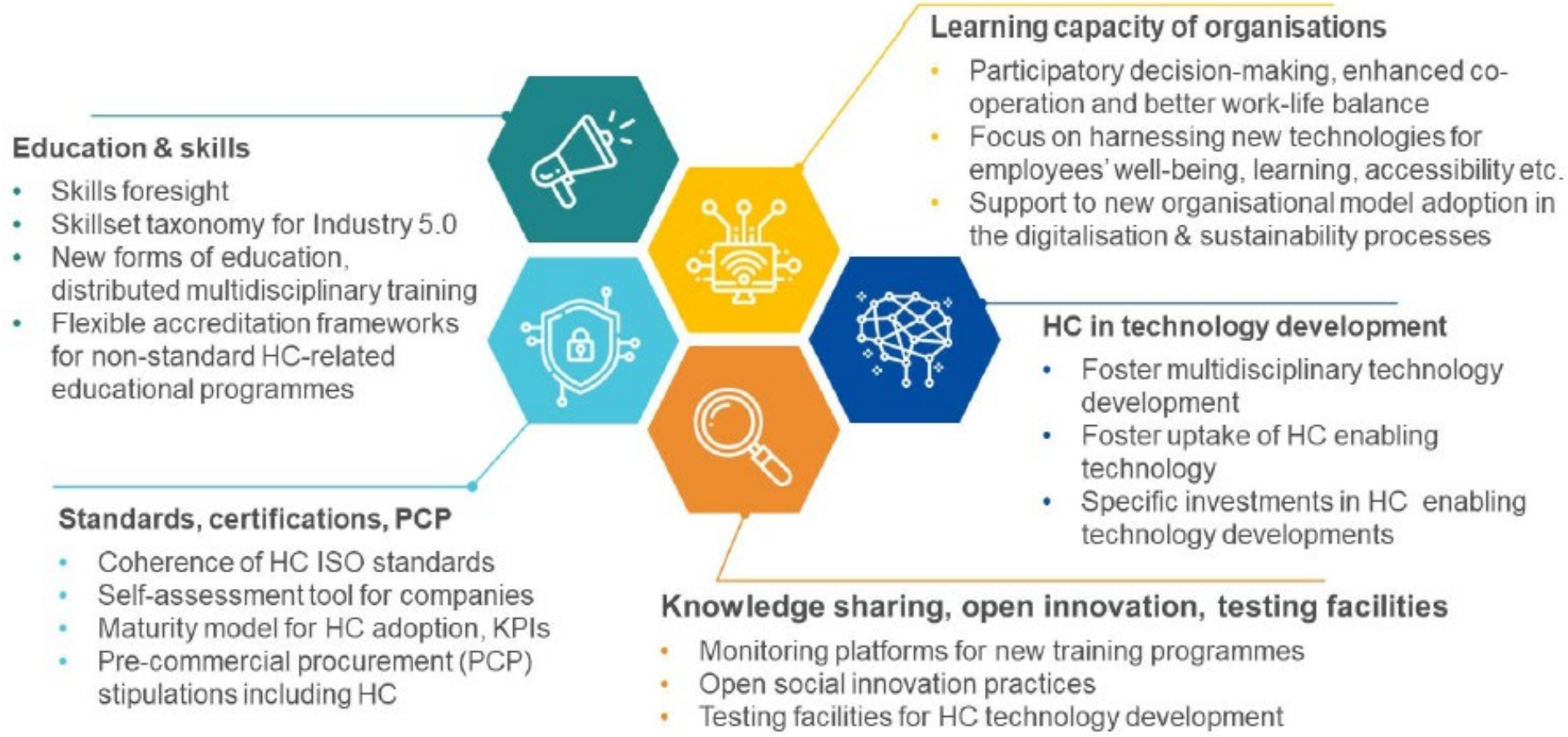
[1]

By realisation of human centricity, values at micro (e.g., worker empowerment, satisfaction),
Meso (e.g., employee retention, profitability) and macro level (e.g., Improved quality of life,
sustainable growth) can emerge.

Industry 5.0 - Human-Centric

Human-centric Research & Innovation Policy Recommendations

Policy actions recommended in EU roadmap, to be implemented by 2035.



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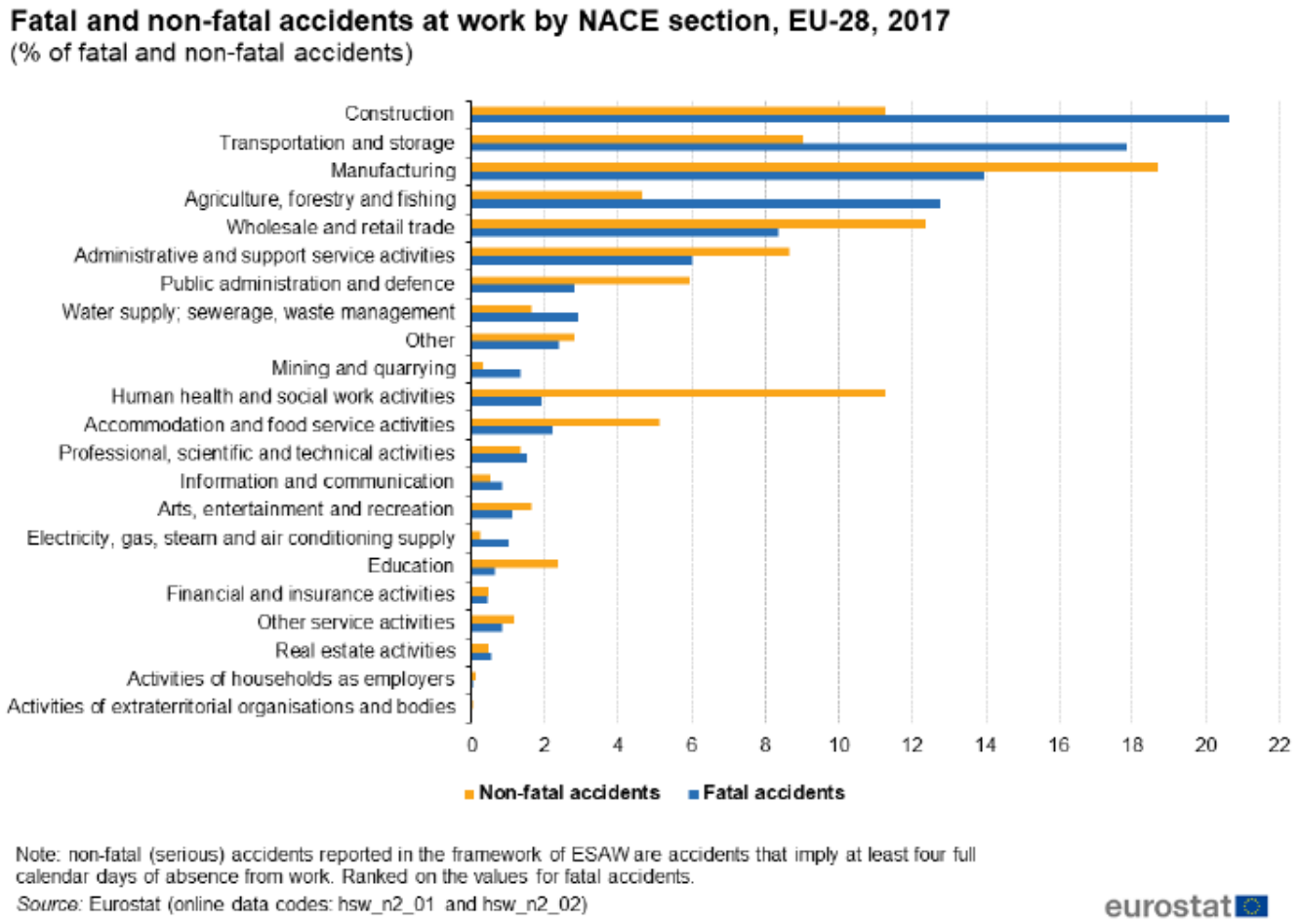
Industry 5.0 - Human-Centric

Safety



[3]

Eurostat data indicates that the sectors with the **highest accident rates are also those that are well-suited for automation.** In 2017, there were reported 3.3 million non-fatal workplace accidents and over 3,500 fatal incidents. Despite the **common fear of job loss** that comes with adopting new technologies, **properly implemented** automation can actually improve workplace safety and promote inclusivity.

Moreover, the introduction of new technologies can lead to increased job satisfaction and overall well-being among employees. It is important to note that many **workplace accidents** may be **under-reported**, and the actual figures could be higher. Additionally, variations in accident rates can be observed among different Member States, influenced by distinct work cultures and reporting systems.

Industry 5.0 - Human-Centric

Standards Related to Human-Centricity at Organisational or Technology Level

Standards related to human centricity	Standards, technical reports, technical specifications on ergonomics	Standards related to aspects of human centricity in specific technologies
- Ergonomics of human-system interaction — Part 210: Human-centred design for interactive systems	- Software ergonomics for multimedia user interfaces	- Artificial intelligence — Overview of trustworthiness in artificial intelligence
- Ergonomics of human-system interaction — Part 220: Processes for enabling, executing and assessing human-centred design within organisations	- Ergonomic design of control centres	- Artificial intelligence — Overview of ethical and societal concerns
- The human-centred organisation — Guidance for managers	- Ergonomic requirements for the design of displays and control actuators	- Common Industry Format for usability (CIF) - General framework for usability-related information
- Guidance on human aspects of dependability	- Ergonomics of human-system interaction — Usability methods supporting human-centred design	- Common Industry Format (CIF) for usability test reports
- Corporate governance of information technology	- Ergonomics of human-system interaction — Specification for the process assessment of human-system issues	- Common Industry Format for Usability (CIF): Context of use description
- Human resource management — Learning and development	- Ergonomics — General approach, principles and concepts	- Common Industry Format for Usability (CIF): User needs report
- Systems and software engineering — System life cycle processes	- Ergonomics of human-system interaction - Auditing procedure for the development of interactive products based on DIN EN ISO 9241-210	- Common Industry Format for Usability (CIF): User requirements specification
- Systems and software engineering — Systems and software Quality Requirements and Evaluation (Square) — Guide to SQuaRE	- Resource-saving application of methods and tools for the anthropocentric design of effective interactive IT systems	- Common Industry Format for Usability (CIF): Evaluation report
- Information technology — Process assessment — Part 5: An exemplar software life cycle process assessment model	- Ergonomics of human-system interaction — Part 820: Ergonomic guidance on interactions in immersive environments including augmented reality, and virtual reality	- Software ergonomics for multimedia user interfaces — Part 1: Design principles and framework, Part 2: Multimedia navigation and control, Part 3: Media selection and combination
- IEEE P70xx series		- Robots and robotic devices — Safety requirements for industrial robots — Part 1: Robots; Part 2: Robot systems and integration
		- Robots and robotic devices — Collaborative robots

[1]

Industry 5.0 - Human-Centric

Standards & Policies - ISO 27500 - The human-centred organization

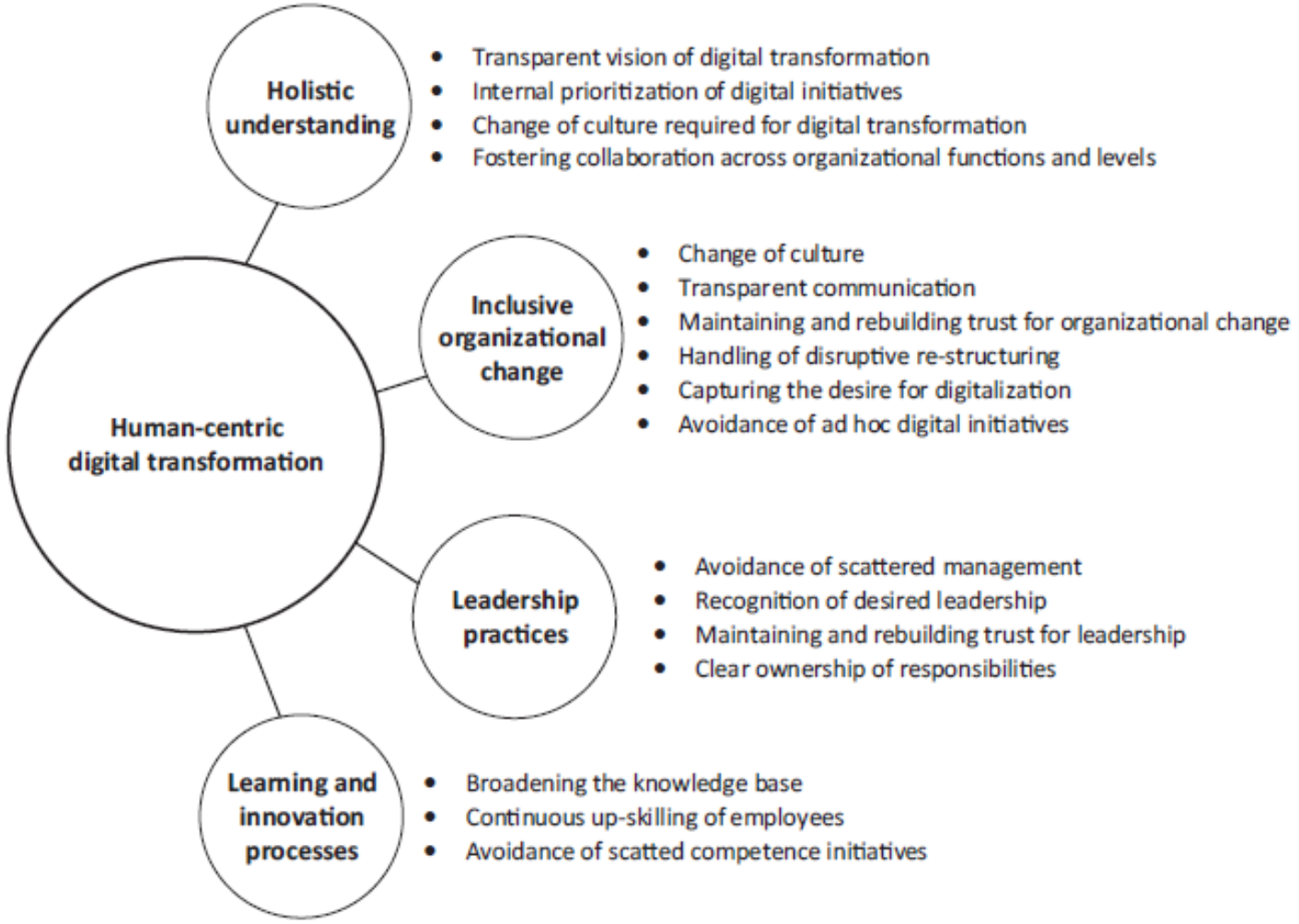
ISO 27500, explains the principles that enshrine the values and beliefs that make an organization human-centred. The term human-centred is used to reflect that organizations not only have an impact on their customers (the users of their products and services), but also on other stakeholders, including their employees, their families, and the wider community. ISO 27500 explains seven principles of human centredness, which are:

- capitalize **on individual differences** as an organizational strength;
- make **usability and accessibility strategic business** objectives;
- adopt a total **system approach**;
- ensure **health, safety and wellbeing are business priorities**;
- value personnel and **create meaningful work**;
- be open and **trustworthy**; and
- act in **socially responsible** ways.

/www.iso.org/obp/ui/en/#iso:std:64239:en

Industry 5.0 - Human-Centric

Organizational Requirements for Digital Transformation Management



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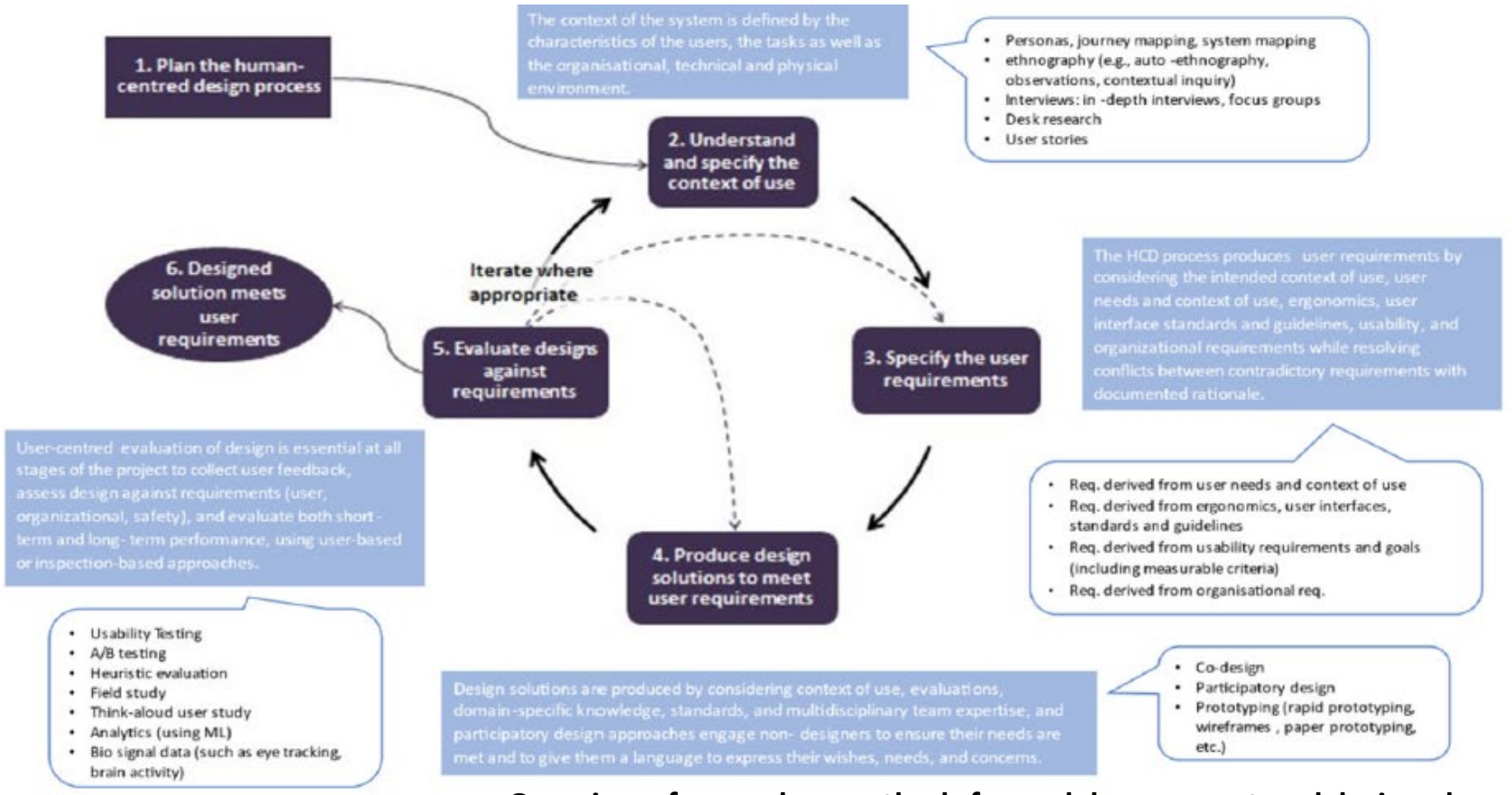
Industry 5.0 - Human-Centric

Human-Centered Design



Overview of exemplary methods for each human-centered design phase

Source: International Organisation for Standardisation. (2016). Ergonomics of human-system interaction. Part 210: Human-centered design for interactive systems (EN ISO 9241-210:2019).

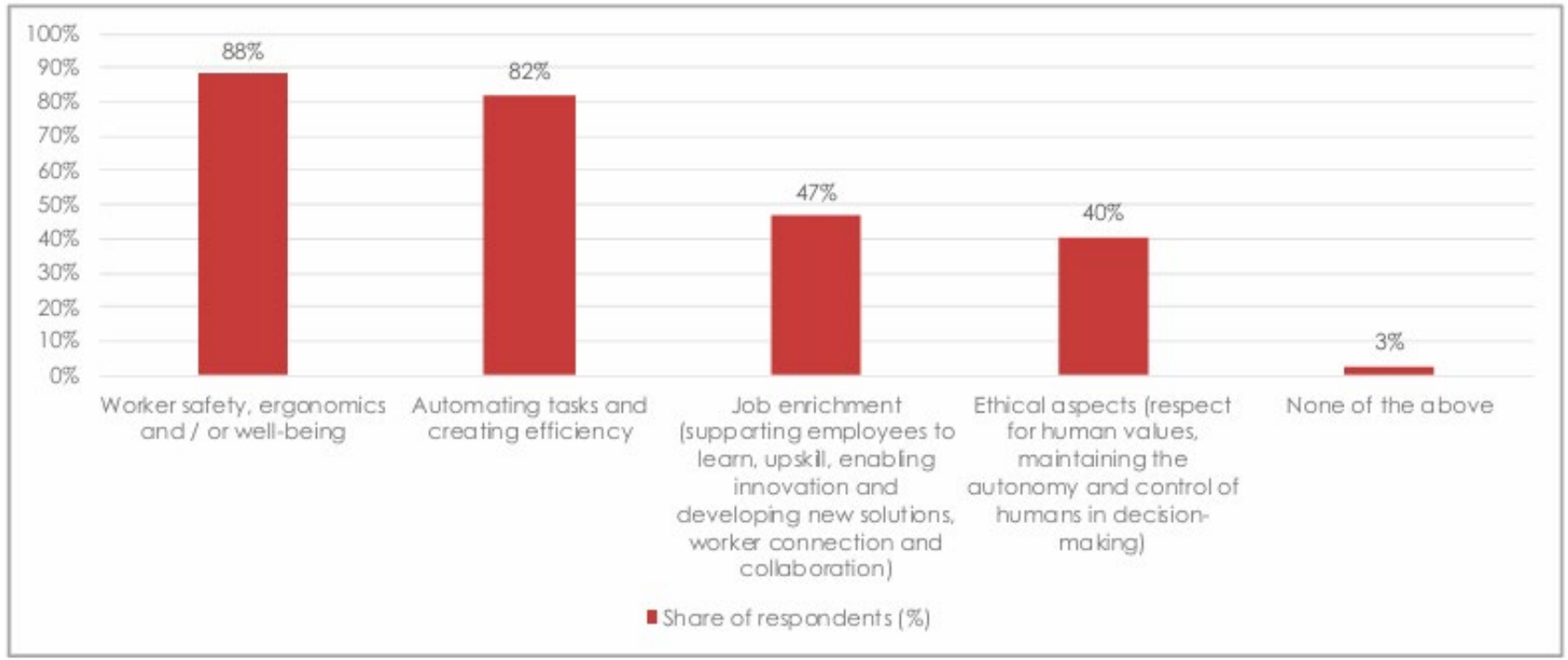
Human-centred design follows an **iterative process consisting of four primary phases**. These phases are revisited in design cycles until the resulting solution aligns with user requirements

1. Plan the process
2. Understand the context of use
3. Specify user requirements
4. Develop design
5. Evaluate designs
6. Ensure the design meets user needs

Industry 5.0 - Human-Centric

Investing in New Human-Centric Technologies

Human centric aspects considered when purchasing manufacturing technologies



Considering that these technologies can be obtained with or without a focus on human-centricity, a survey was conducted among manufacturing companies to see if they took human-centric factors into account when investing in new technology or software.

[1]

Industry 5.0 - Human-Centric

Skilled Workforce

A skilled workforce is critical for effectively utilizing technologies aimed at human-centered outcomes. Companies must invest in training employees, especially in specialized areas like artificial intelligence, to fully harness the benefits of human-centric technology. The 2019 World Manufacturing Forum Report titled "Skills for the Future of Manufacturing" offers detailed insights into the skills required for this purpose.

[6] 2019 World Manufacturing Forum

Industry 5.0 - Human-Centric

Transversal Skills

Human creativity, emotional intelligence and innovation remain irreplaceable, even if:

14% of jobs are **highly automatable**

32% of jobs **might change substantially** due to AI within this decade

Both workers and employers value transversal skills that help to adapt the changing work landscape, particularly in the green and digital transitions.

24.5% of candidates lack transversal skills.

SMEs in the EU see a growing importance of these transversal skills:

68% for soft skills

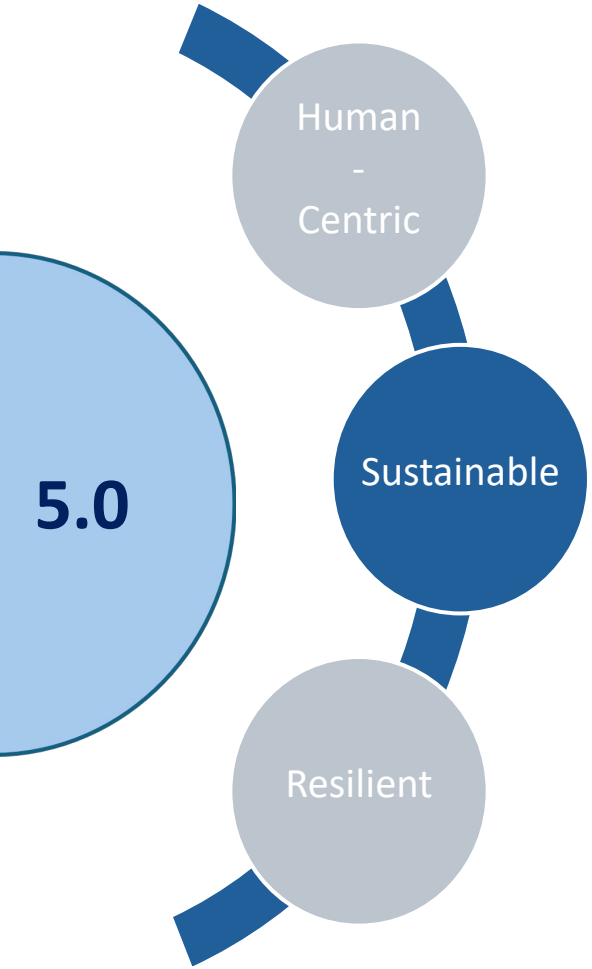
62% for digital skills

42% for green skills

Transversal skills like critical thinking, teamwork, and learning skills are essential for work, education and daily life. Developing and recognizing these skills play an important role in promoting sustainable economic growth, social inclusion, and competitiveness.

https://year-of-skills.europa.eu/transversal-skills_en

Industry 5.0 - Sustainable



Urgency of Climate Change & Resource Scarcity

- *Need for Rapid Action:* Traditional linear economic models are exhausting resources and contributing to climate instability.
- *Critical Climate Threat:* Reports from the IPCC emphasize the urgent need for rapid decarbonization and a **transition to renewable energy sources**.

Transitioning from Linear to Circular Models

- *Circular Economy*: Focus on eliminating waste by continuously circulating materials through **reuse, repair, and recycling.**
- *Policy Support:* The EU Circular Economy Action Plan offers a strategic framework for change

Aligning with EU Policy Goals

- *European Green Deal:* Aims for climate neutrality by the year 2050.
- *Digital Transformation in Europe:* The importance of **responsible and ethical digital advancements**.
- *Economy That Benefits People:* **Social justice, equitable working conditions, and inclusive economic growth**.

Embracing a Regenerative Approach

- *Reevaluating Production Processes:* Reduce ecological impact throughout product life cycles.
- *Key Approaches:* **Design products with durability, reparability, and recyclability in mind**, establish closed-loop systems to recapture and repurpose materials, move towards product-service systems that prioritize access over ownership.

Used various resources included in the presentation.

Industry 5.0 - Sustainable

Some Initiatives From the European Green Deal

Making transport sustainable for all

55%
reduction of emissions from cars by 2030

50%
reduction of emissions from vans by 2030

0
emissions from new cars by 2035

Leading the green industrial revolution

Over €100 billion
is the value of EU's net-zero start-ups ecosystem in 2021, doubling since 2020

More than 400 GW
of wind and solar renewable energy production capacity in the EU in 2022, an increase of over 25% compared to 2020

4.5 million
green jobs in the European economy in 2019 up from 3.2 million in 2000

Cleaning our energy system

42.5%
new renewable energy target for 2030 (with the ambition to reach 45%)

11.7%
improvement in energy efficiency by 2030

Renovating buildings for greener lifestyles

To complement new EU rules on buildings and guide Member States' efforts, there is a new indicative national benchmark of 49% of renewable energy in the buildings sector.

https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/european-green-deal/delivering-european-green-deal_en#making-transport-sustainable-for-all

Industry 5.0 - Sustainable

Sustainable Development Goals

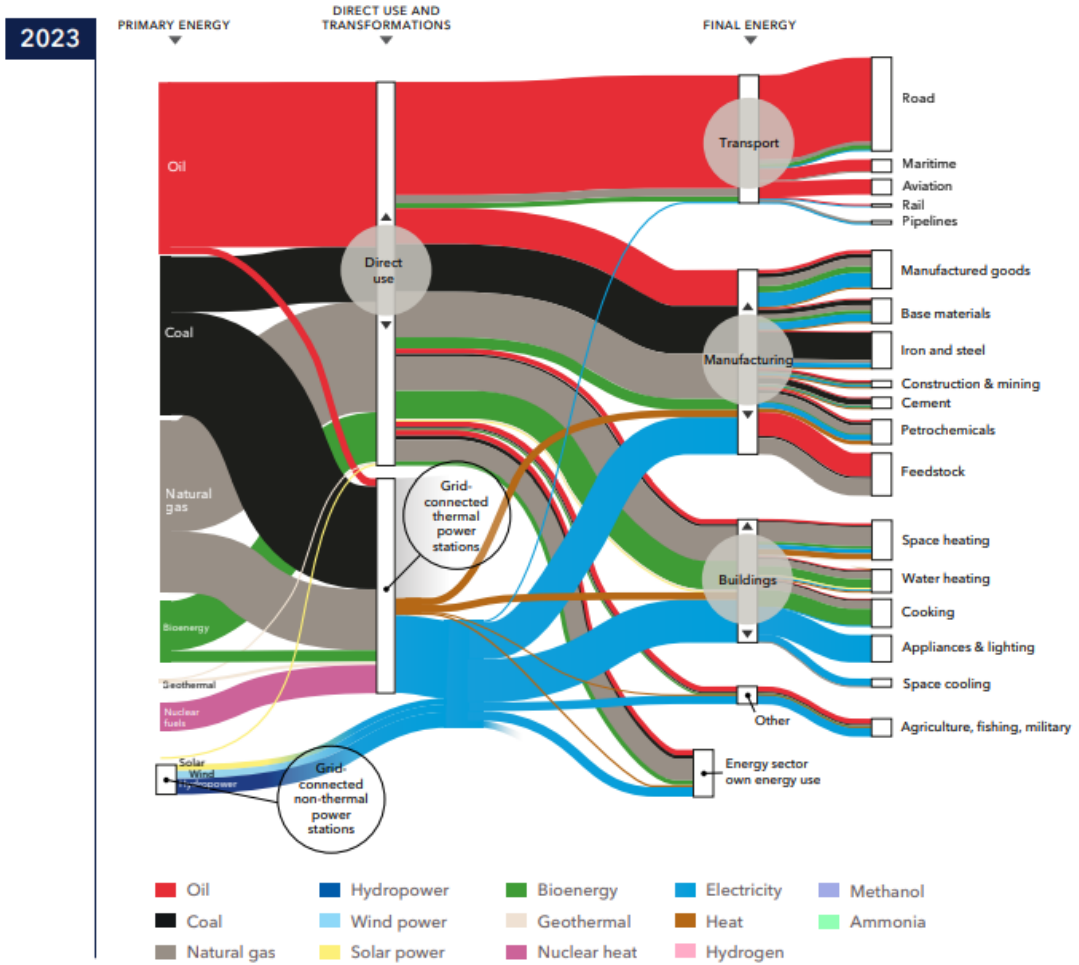
https://sdgs.un.org/goals

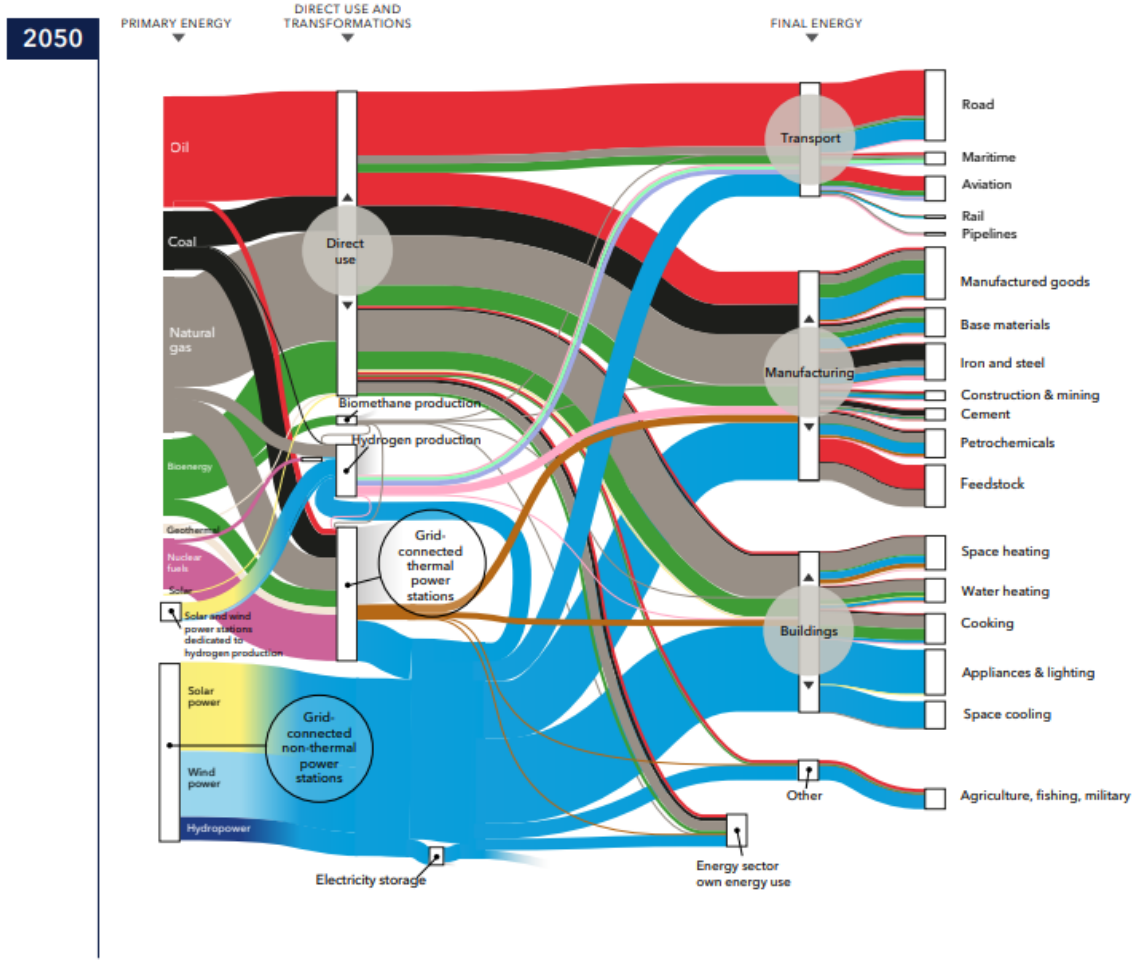
https://dashboards.sdgindex.org/chapters

Developed by United Nations → Linked to Industry 5.0

Industry 5.0 - Sustainable

Comparison of Energy Flows Outlook 2050





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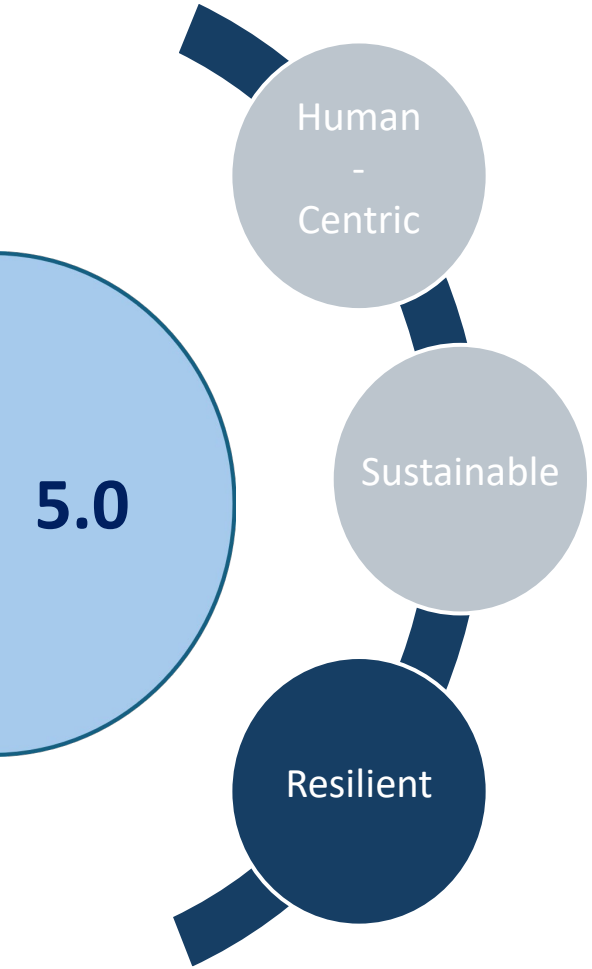
Industry 5.0 - Resilient



Insights from Crises (e.g., COVID-19)

- *Vulnerability of Global Systems:* **Global disruptions** can occur rapidly when one region enters lockdown.
- *Need for Readiness:* **The necessity of contingency plans**, diverse sourcing strategies, and the **adoption of agile technologies**.

Disruptions in Global Supply Chains

- *Risk Exposure*: Border closures and lockdowns have exposed **the fragility of streamlined, single-source supply chains**.
- *Necessity for Diversification:* The establishment of. **local and regional production centers along with multiple supplier networks**
- *Reassessing Efficiency:* Incorporate redundancy and flexibility even if it incurs higher costs to enhance resilience.

Geopolitical Changes & Global Uncertainties

- *Increasing Protectionism:* Trade conflicts underline the importance of strategic independence and **less reliant global dependencies**.
- *Resource Constraints:* The competition for essential materials necessitates efficient resource use and **circular economy practices**.
- *Strategic Independence for Europe:* Europe should reduce its dependence on international suppliers and invest in alternative resources.

Anticipating Future Disruptions

- *Foresight & Scenario Planning:* Monitor **emerging risks and trends to prevent crises before they escalate**.
- *Flexibility & Adaptability:* Implement **modular production systems, agile manufacturing** etc.
- *Nurturing a Resilient Culture:* **Empower workers, promote teamwork, and support proactive problem-solving initiatives.**

Used various resources included in the presentation.

Industry 5.0 - Resilient

Resilience and Projects / Disruptions in Projects

- Unexpected events that impact a project's progress, cost, or performance.
- Can be **internal (endogenous)** or **external (exogenous)**.
- May lead to **delays, financial losses, resource shortages, or even project failure**

Exogenous Disruptions: Forces **outside** the immediate control of the project or organization

Examples: COVID-19 pandemic, Political clashes, Bushfires, Hurricanes, Typhoons, Cyclones, Droughts, Sea-level rise, Migration due to climate change and war, 11 March 2011 tsunami in Japan, 2019/20 Australian Bushfires

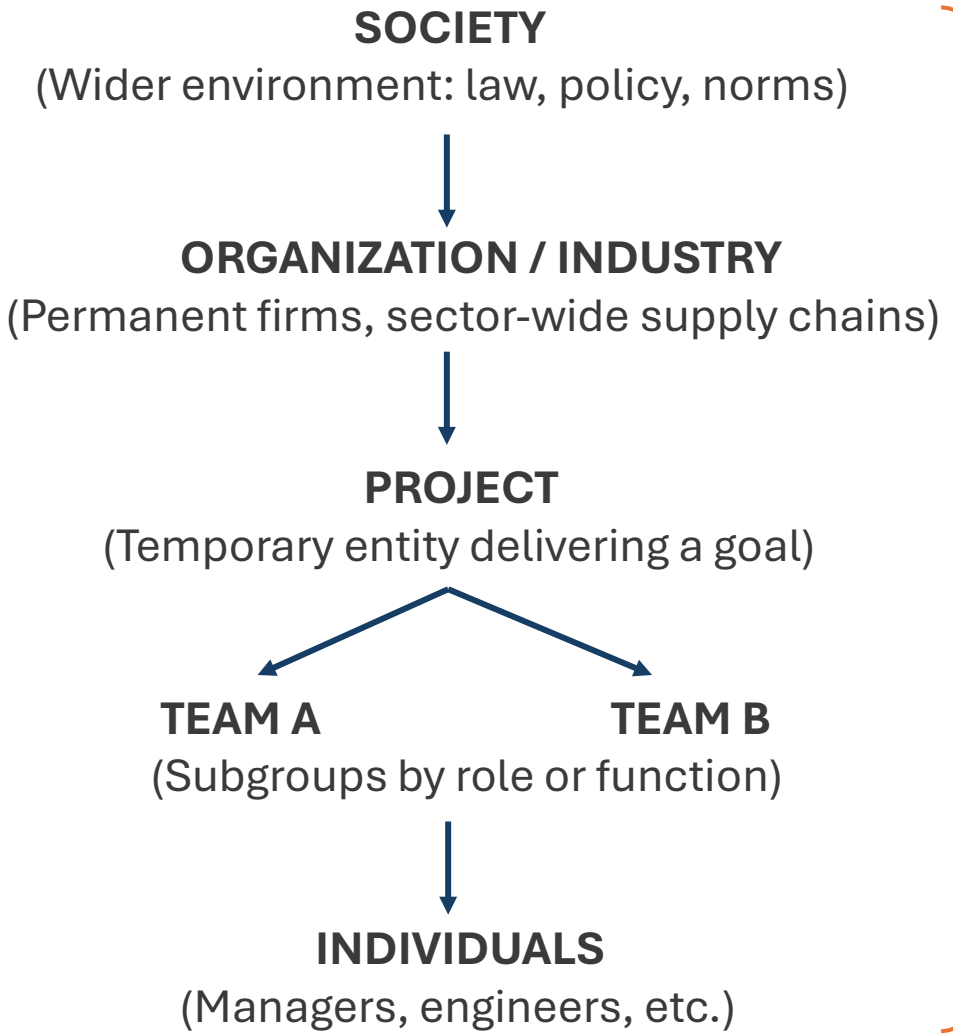
Endogenous Disruptions: They arise from **within the organization, the project team, or the supply chain itself**

Examples: Counterfeit items (branded to imitate original products), Fraudulent items, Cultural and Behavioral Factors, Human Errors, Mismanagement, Lack of Coordination between Teams and Internal Conflicts etc.

[9]

Industry 5.0 - Resilient

Systems Thinking & Multi-Level Perspective



[9]

Institutional resilience deals with how well formal institutional structures can sustain shocks and support recovery. This involves actions across the community and public and private domains.

Organizational resilience focuses on shocks to organizations, business continuity, organizational reliability, resource buffers, capabilities to deploy resources under crisis, adaptability of business models, and organizational responses to extreme contexts.

Project resilience is the capacity to organize under a variety of scenarios, including disruptions in the form of shocks or stressors

Team resilience is defined as the ability of teams to perform under a variety of conditions and towards team goals.

Psychological resilience focuses on the adaptive strength of individuals to face disruptions and variations in their life and careers

Industry 5.0 - Resilient

Cybersecurity

Increased Digital Dependence: Industry 5.0 relies heavily on digital technologies, that is vulnerable to technical disruptions and cyberattacks.
Ensuring Resilience: Cybersecurity measures are essential for ensuring the resilience of Industry 5.0 against disruptions.
AI-Driven Threats and Defenses: AI can be used for cybersecurity, but also creates risks through AI-related cyberattacks.
Certificates: Certifications such as TUV is important to ensure the products reliability and security.

IOT devices certification by TÜV	TÜV (Technischer Überwachungsverein) certification for IoT devices holds a critical role in Industry 5.0. As IoT devices are integral for data collection and automation in this context, such certification becomes paramount in guaranteeing the reliability and security of these devices.

Key Aspects of Cybersecurity

- Data Protection: Cybersecurity protects sensitive data from unauthorized access and breaches.
- System Integrity: It ensures the integrity and availability of digital systems and infrastructure.

[1,3]

Industry 5.0 - Resilient

Cybersecurity Govarnence – NIST Cubersecurity Framework(CSF) 2.0

The Cybersecurity Framework (CSF) 2.0 is designed to help organizations of all sizes and sectors — including industry, government, academia, and nonprofit — to manage and reduce their cybersecurity risks. It is useful regardless of the maturity level and technical sophistication of an organization's cybersecurity programs.

Actions that support GOVERN, IDENTIFY, PROTECT, and DETECT should all happen continuously, and actions that support RESPOND and RECOVER should be ready at all times and happen when cybersecurity incidents occur.

All functions have vital roles related to cybersecurity incidents. GOVERN, IDENTIFY, and PROTECT outcomes help prevent and prepare for incidents, while GOVERN, DETECT, RESPOND, and RECOVER outcomes help discover and manage incidents.

https://www.nist.gov/cyberframework

Industry 5.0 - Resilient

Cybersecurity Govarnence – Risk Management Communication

The CSF provides a basis for improved communication regarding cybersecurity expectations, planning, and resources. The CSF fosters bidirectional information flow (as shown in the top half of the figure) between executives who focus on the organization's priorities and strategic direction and managers who manage specific cybersecurity risks that could affect the achievement of those priorities.

The CSF also supports a similar flow (as shown in the bottom half of the figure) between managers and the practitioners who implement and operate the technologies. The left side of the figure indicates the importance of practitioners sharing their updates, insights, and concerns with managers and executives

https://www.nist.gov/cyberframework

Industry 5.0 - Resilient

Risk Management vs. Resilience

Aspect	Risk Management	Resilience
Definition	Identifies, assesses, and **mitigates known risks** to minimize their impact.	Ability to perform under a variety of conditions, including disruptions (both known and unknown).
Approach	Preventive → **tries to anticipate and reduce risks before they occur.**	Adaptive → **assumes disruptions will happen and prepares for flexible responses**.
Focus	Managing specific threats that can be predicted and quantified.	Ensuring the **system as a whole can continue functioning despite shocks**.
Response to Uncertainty	Works best with known unknowns (quantifiable risks with probability estimates e.g. storm).	Addresses unknown unknowns (emerging, unpredictable events e.g. global crisis like pandemic).
Key Methods	Risk assessments, mitigation plans, contingency buffers, compliance measures.	Redundancy, adaptability, learning from past disruptions, cross-functional collaboration.
Time	Short to medium-term (within project lifecycle).	Long-term and continuous improvement, beyond individual projects.
Mindset	“How can we avoid failure?”	“How can we recover and adapt from failure?”
Handling Disruptions	Tries to eliminate or control risks before they occur.	Accepts that some disruptions are inevitable and focuses on recovery.
Example in Projects	A project team identifies supply chain risks and finds alternative vendors before disruptions happen.	A project team rapidly adapts to an unexpected supplier shutdown by reallocating resources and modifying plans.

What is Happening in Other Industries?

Intelligent Healthcare

- Manufacturing of personalized implants
- Performing surgeries in a more precise way
- Reduced Error Rates = Better Patient Care

Supply Chain Management

- Minimize the losses and errors
- Increase margins, reduce operational costs
- Efficient communication between the stakeholders

Cloud Manufacturing

- Low cost manufacturing process
- Reliability, high quality, on-demand capabilities
- Eliminate the long haul delivery requirements

[6]

What is Happening in Other Industries?

Smart Education

- Improves visualization and creativity
- Interactive Learning Experience
- Real-time blended teaching and learning

Manufacturing / Production

- Improved Productivity
- Innovation and higher quality products
- Energy Efficiency

Disaster Management

- Ability to handle consequences of the disaster
- Used in search and rescue operation
- Enhance the level of preparedness

[6]

What is Happening in Other Industries?

Key Technologies of Industry 5.0 and Applications

Industry 5.0 Applications	Edge computing	Digital twins	Cobots	IoE	AI	Big data	Blockchain	6G and beyond	Swam networking	Network slicing	Extended reality	Private mobile network
Intelligent healthcare	H	M	L	H	H	H	H	H	L	H	H	M
Cloud manufacturing	H	H	H	H	H	H	H	H	H	H	H	M
Supply chain management	M	L	L	H	H	H	H	H	H	L	L	L
Manufacturing/Production	H	H	H	H	H	H	H	H	H	H	H	H
Education	H	M	L	M	M	M	M	H	L	H	H	M
Human–cyber–physical systems	H	H	H	H	H	H	H	H	H	H	H	H
Disaster management	H	M	M	H	H	H	M	H	H	M	H	M

H High Utilization M Medium Utilization L Low Utilization

[6]

What is Happening in Other Industries?

Architecture Engineering Construction Industry

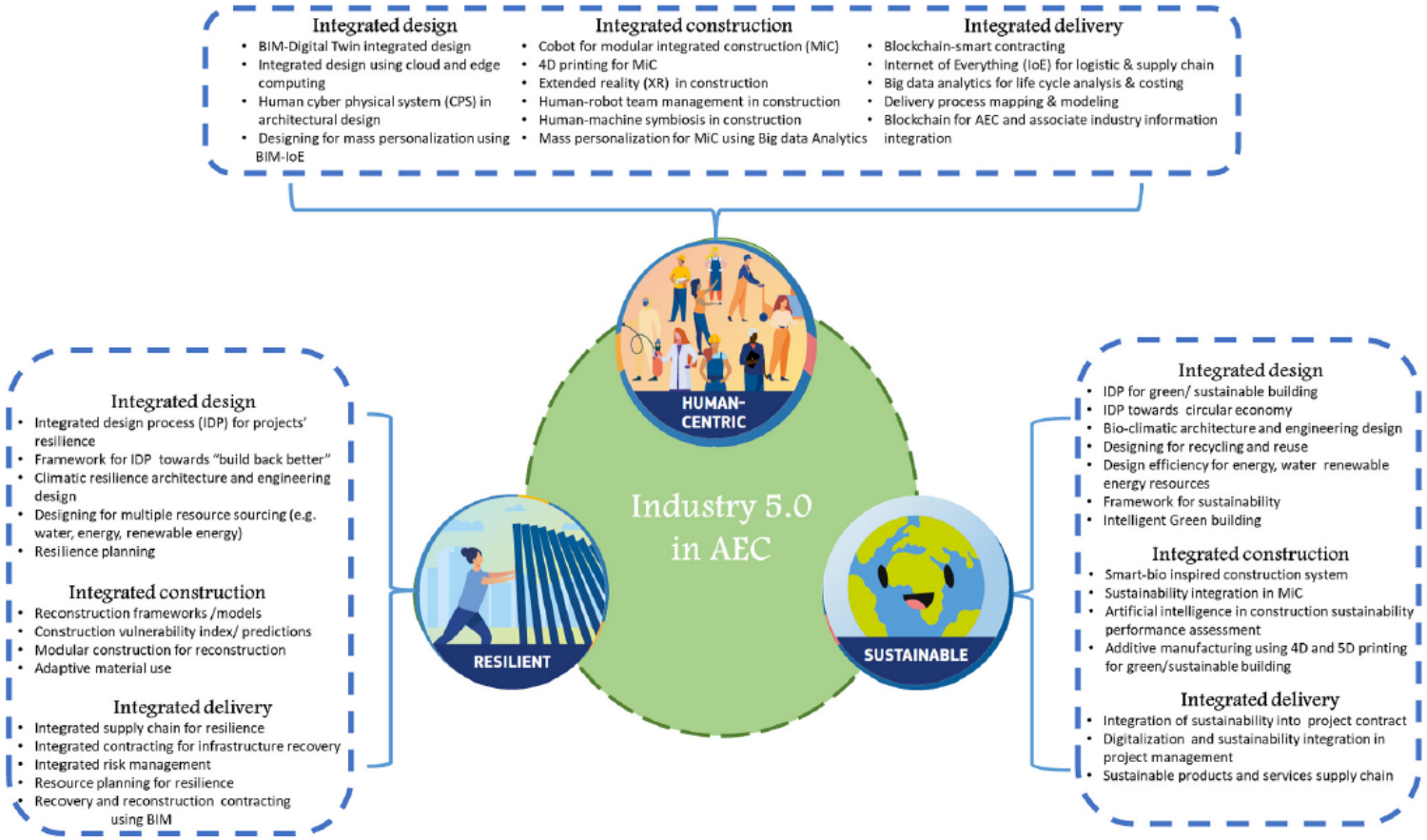


Fig. 14. Prospective research pathways towards achieving Industry 5.0 core values in the AEC industry.

[10]

Integrated Design, Integrated Construction, and Integrated Delivery becoming widely important under industry 5.0

- **Addressing Fragmentation:** IPs promote collaboration and information sharing to overcome these challenges
- **Enhancing Collaboration:** IPs are collaborative processes where individuals share skills, expertise, and knowledge to achieve optimal solutions
- **Improving Project Outcomes:** IPs can lead to improved project performance and reduced waste

Enabling Technologies

- BIM
- Other Technological Enablers

What is Happening in Other Industries?

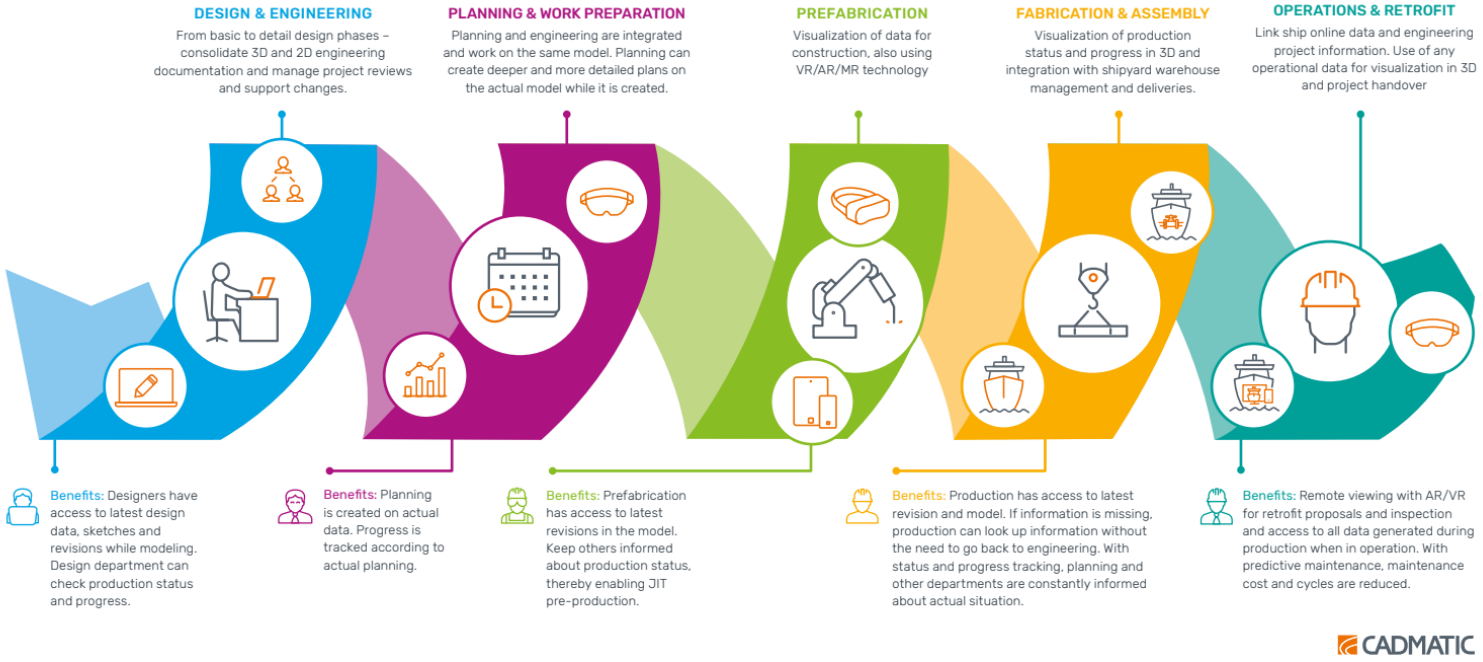
Maritime Industry – Digitalization Needs

Integrated practices are widely becoming important in maritime industry as well in the era of Industry 5.0. The increasing complexity of shipbuilding projects involving a "spider-web"- type network of information exchanges among dispersed stakeholders necessitates integrated communication and data flow [16].

Current

naval-architect.io

Future

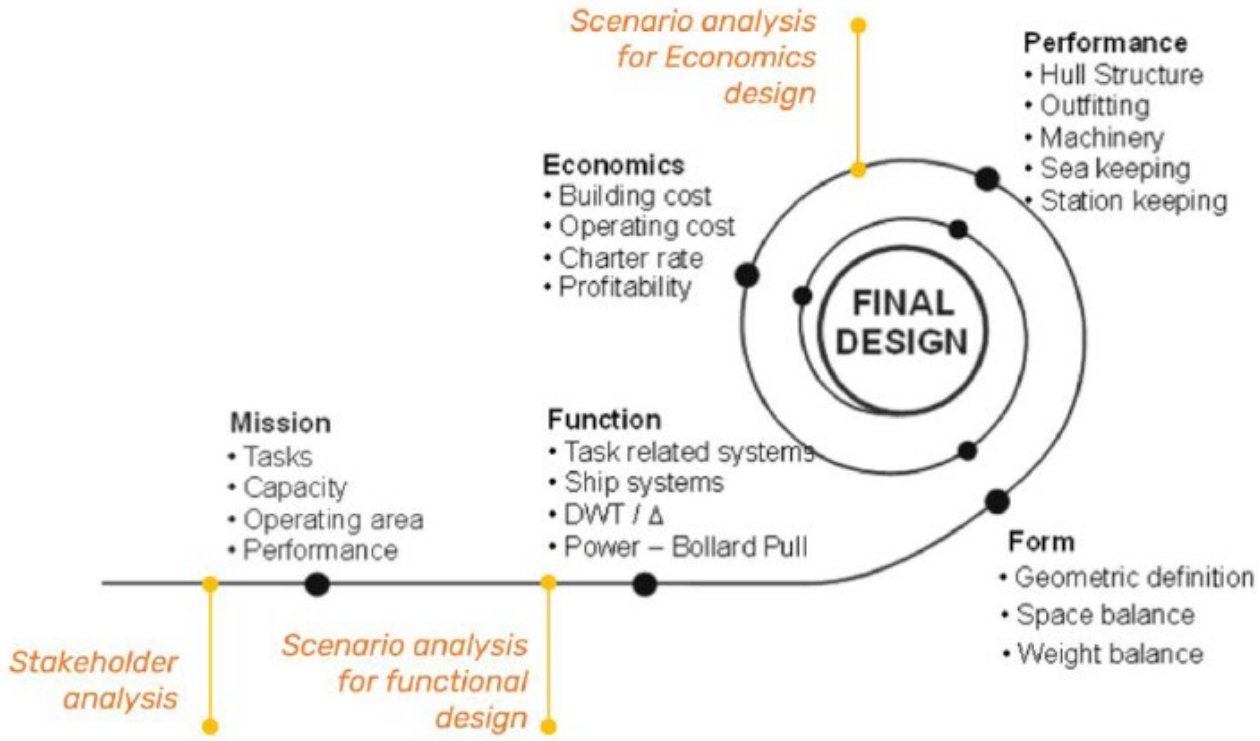


Cadmatic, 2023

https://www.cadmatic.com/en/resources/publications-and-brochures/

What is Happening in Other Industries?

Maritime Industry – Ship Design Process under Industry 5.0



Moreover, there are further research on how Industry 5.0 can transform the ship design process and methodology. Traditionally, the ship design process has been viewed as a "design spiral." However, by explicitly incorporating a human-centric perspective, we can enhance this process through stakeholder analysis and scenario analysis that focus on functional and economic design.

Additionally, it is beneficial to integrate practices from other fields, such as project management and futures studies, to better navigate the complexities and uncertainties inherent in ship design.

[15]

What is Happening in Other Industries?

Maritime Industry – Autonomous Ships

MASS autonomy level	Details	Simplified (Source: Bureau Veritas 2019)
Degree One	Ship with automated processes and decision support: Seafarers are on board to operate and control shipboard systems and functions. Some operations may be automated and, at times, unsupervised, but with seafarers on board ready to take control.	**Smart Ship** Directed by humans. Rely on the system and sensors for support in collecting data and making decisions.
Degree Two	Remotely controlled ship with seafarers on board: The ship is controlled and operated from another location. Seafarers are available on board to take control and operate the shipboard systems and functions.	**Semi-Autonomous Ship** Human delegated or supervised. Rely on the system to make decisions and/or initiate actions.
Degree Three	Remotely controlled ship without seafarers on board: The ship is controlled and operated from another location. There are no seafarers on board.	**Semi-Autonomous Ship** Same as above.
Degree Four	Fully autonomous ship: The ship's operating system can make decisions and determine actions.	**Fully Autonomous Ship** Unmanned Ship. Requires no input from humans except in an emergency.

Source: International Maritime Organization (2018).

Factors of MASS	Questions
Technology feasibility	Is the technology ready for large-scale operation?
Labour market dynamics	Is labour expensive? Is there a labour shortage?
Knowledge and skills	Are users able to master the technology?
Social acceptance	Does society accept the technology?
Regulations and governance	Are regulations ready? Is the authority supportive?
Economic benefits	Has a sound business model been drawn up?

Source: Lagdami (2022).

[12]

Autonomous ships, are defined as vessels capable of operating independently of human interaction to varying degrees. The level of automation for these ships can vary and can even change during a voyage.

The introduction of autonomous ships is seen as a powerful technological advancement that will require a reconfiguration of the maritime workforce. While some traditional skills focused on manual operations may become outdated, this transition towards automation also presents opportunities for new technology-driven roles. Workers will increasingly need to focus on technology management and data analysis, as certain tasks are automated.

https://glamsquadmagazine.com/the-worlds-first-fully-electric-autonomous-cargo-vessel-unveiled-in-norway/
https://tipbandit.com/technology/yara-birkeland-fully-electric-autonomous-cargo-ship/

What is Happening in Other Industries?

Maritime Industry - Net Zero Goals – SDG 13

2023 IMO Strategy

1. Carbon intensity of the ship to decline through further improvement of the energy efficiency for new ships

2. Carbon intensity of international shipping to decline

to reduce CO2 emissions per transport work, as an average across international shipping, by at least 40% by 2030,compared to 2008)

3. Uptake of zero or near-zero GHG emission technologies, fuels and/or energy sources to increase

uptake of zero or near-zero GHG emission technologies, fuels and/or energy sources to represent at least 5% striving for 10% of the energy used by international shipping by 2030; and

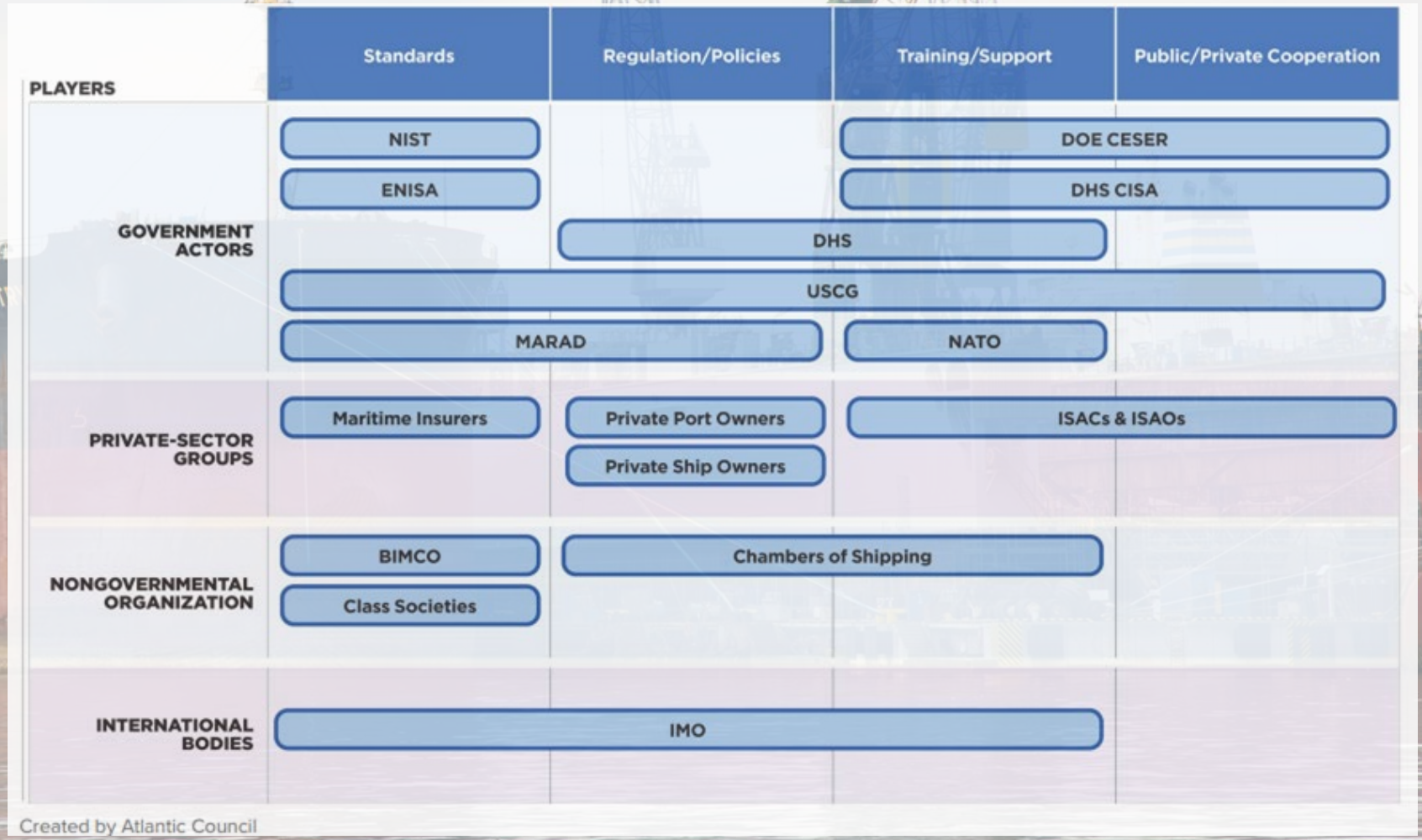
4. GHG emissions from international shipping to reach net zero

to peak GHG emissions from international shipping as soon as possible and to reach net-zero GHG emissions by or around, i.e. close to, 2050

https://www.imo.org/en/OurWork/Environment/Pages/2023-IMO-Strategy-on-Reduction-of-GHG-Emissions-from-Ships.aspx

What is Happening in Other Industries?

Maritime Industry - Cybersecurity



https://www.atlanticcouncil.org/wp-content/uploads/2021/10/Cyber-Maritime-Final-Report.pdf

What is Happening in Other Industries?

Aerospace Industry

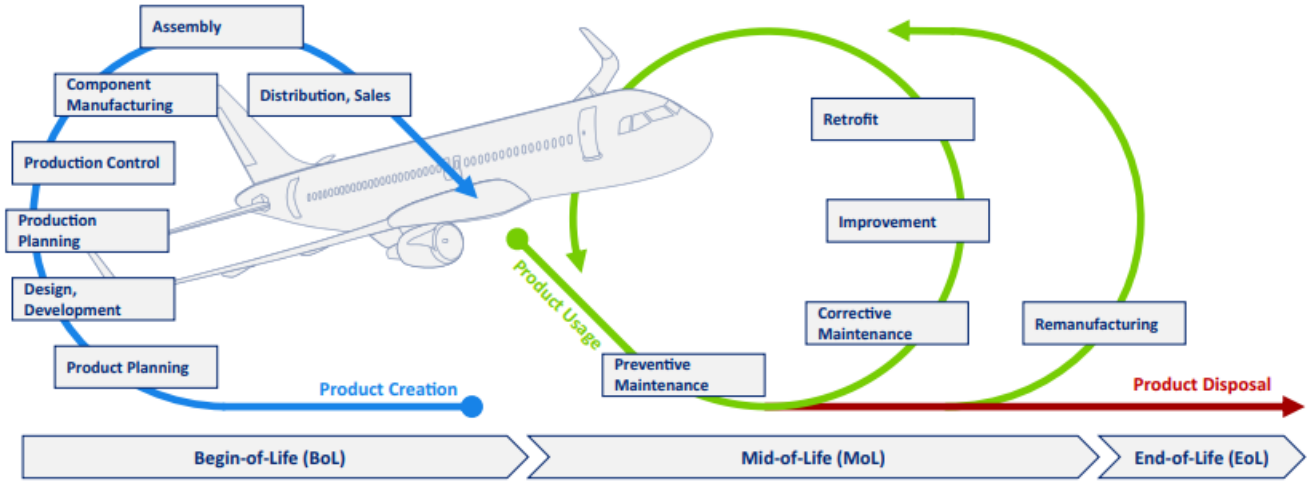


Fig. 3 An aircraft's lifecycle from product creation to product disposal (based on [16, 17])

Characteristics of Aircraft Industry

- High proportion of manual processes;
- Dependence on expert knowledge (e.g., classifying defects);
- R-Processes, like, remanufacture, reuse and retrofit systems, subsystems, and components;
- Fixed position final assembly;
- Historically grown processes;
- Distributed production with a large number of suppliers;
- High levels of inspection, testing, occupational health and safety, certification, and documentation

Challenges in Aircraft Industry

Integrational challenges
- Missing standardized structure & semantic
- Complexity of integration
- Interfaces

Organizational challenges
- Qualified staff
- Collaboration
- Value for management

Compliance-related challenges
- Data protection/ownership

[22]

What is Happening in Other Industries?

Applications from Aerospace Industry

AR-assisted H2 Leakage Inspection

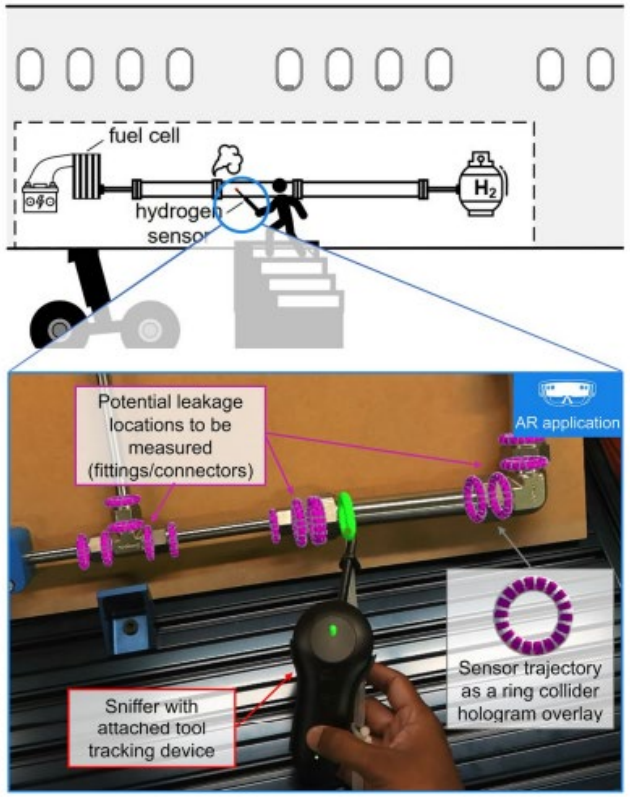


Fig. 4 Top: Use case of an AR-assisted H_2 leakage inspection on aircraft components; Bottom: AR application for measuring the leakage of fittings in a pipe system with a sniffing sensor

Digital Production Process Twin

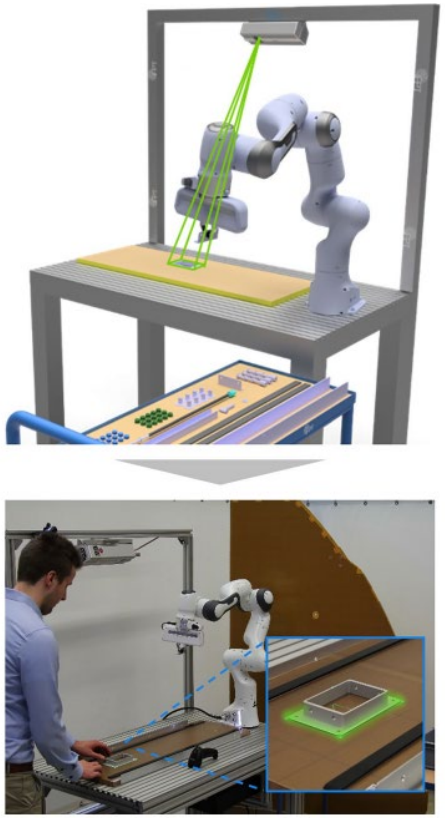


Fig. 6 The *Digital Production Process Twin* of an assembly station for hybrid assembly of cabin interior components (based on [21])

Human Action Recognition (HAR)-based progress detection in manual assembly

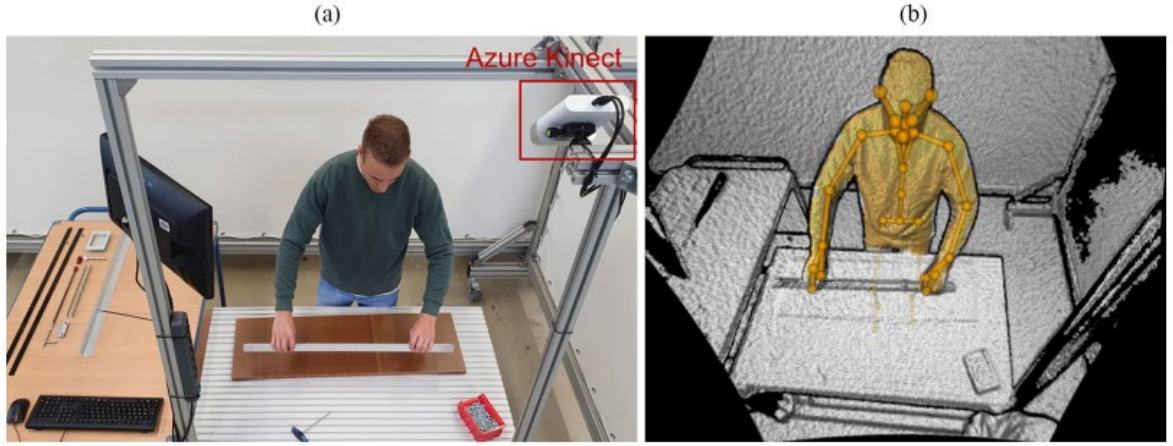


Fig. 6 **a** Workstation for multi-variant assembly processes in aircraft interior production; **b** Azure Kinect depth image and skeleton reconstruction [62]

[23]

Challenges

Some challenges mentioned from the various resources in this document include;

Category	Specific Barriers
Technological	Lack of interoperability and standardization among different systems and platforms.
	Immature or unreliable AI technologies that leads to performance issues or unexpected outcomes.
	Difficulties in integrating AI and robotics into existing manufacturing workflows and processes.
Economic	High implementation costs for AI, robotics, and other Industry 5.0 technologies, especially for small medium sized enterprises (SMEs)
	Uncertain return on investment and difficulty in quantifying the benefits of Industry 5.0 initiatives.
	Potential for job displacement and economic inequality due to automation.
Human and Societal	Lack of skilled workforce with the necessary technical and cognitive skills to work alongside AI and robots.
	Resistance to change and cultural barriers to adopting new technologies and working practices.
	Ethical concerns surrounding AI, data privacy, algorithmic bias, and the responsible use of technology.
Organizational	Lack of strategic vision and leadership commitment to drive Industry 5.0 transformation.
	Siloed organizational structures and lack of collaboration across departments.
	Inadequate infrastructure, including data storage, network capacity, and cybersecurity measures.

Challenges

Some challenges mentioned from the various resources in this document include;

Fig. 5. A tri-dimension architecture of implementing Industry 5.0.

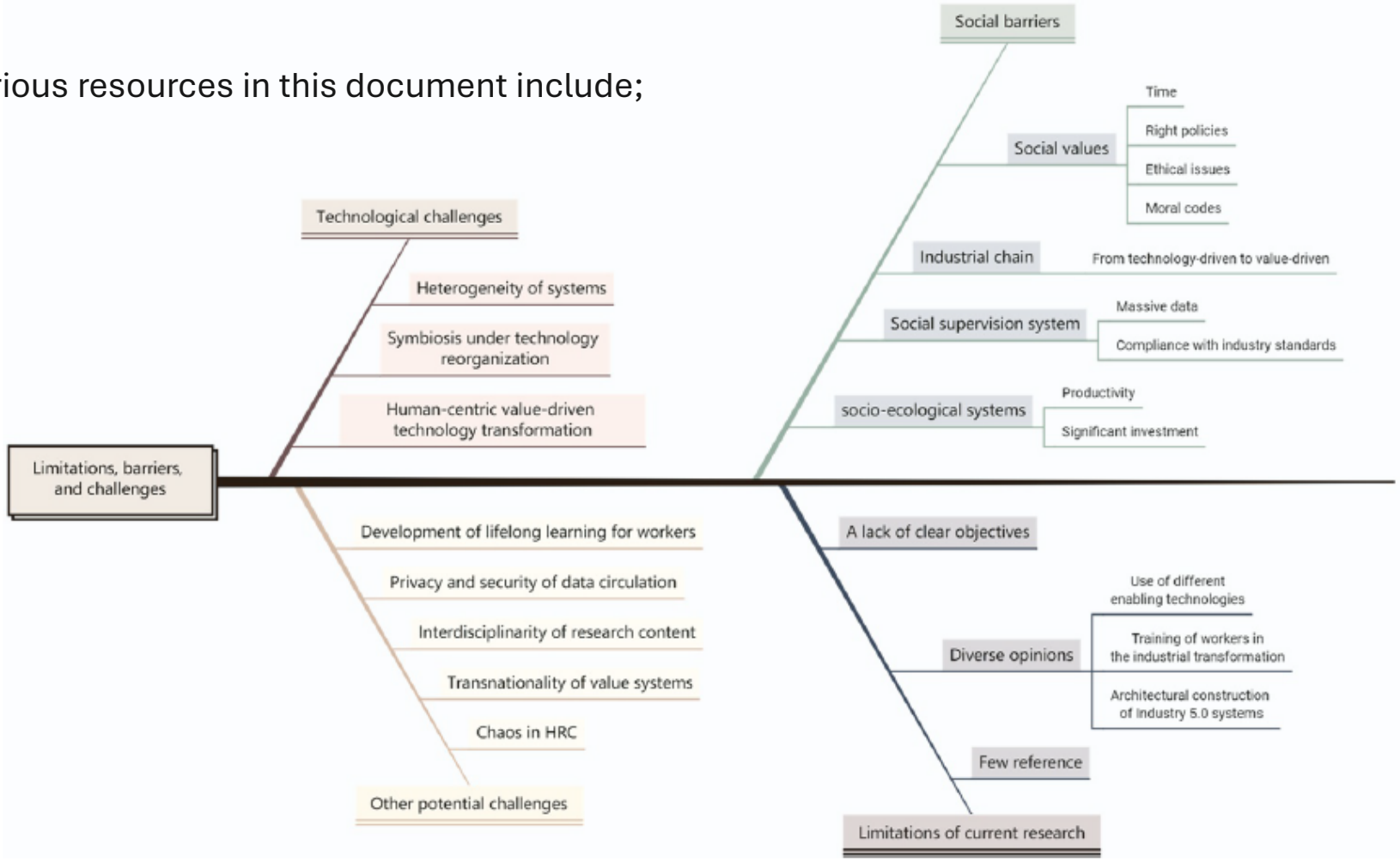


Fig. 6. Limitation, Barriers, and Challenges towards Industry 5.0.

[21]

Summary & Additional Notes

Industry 5.0

Key Pillars

Human - Centric

- Well-being and Satisfaction
- Human Input in Decision-Making
- Skill Development and Continuous Learning
- Security and Stability

Sustainability

- Circular Economy Transition
- Maximize Material and Energy Efficiency
- Design for Sustainability Across the Value Chain
- Alignment with EU Policies

Resilient

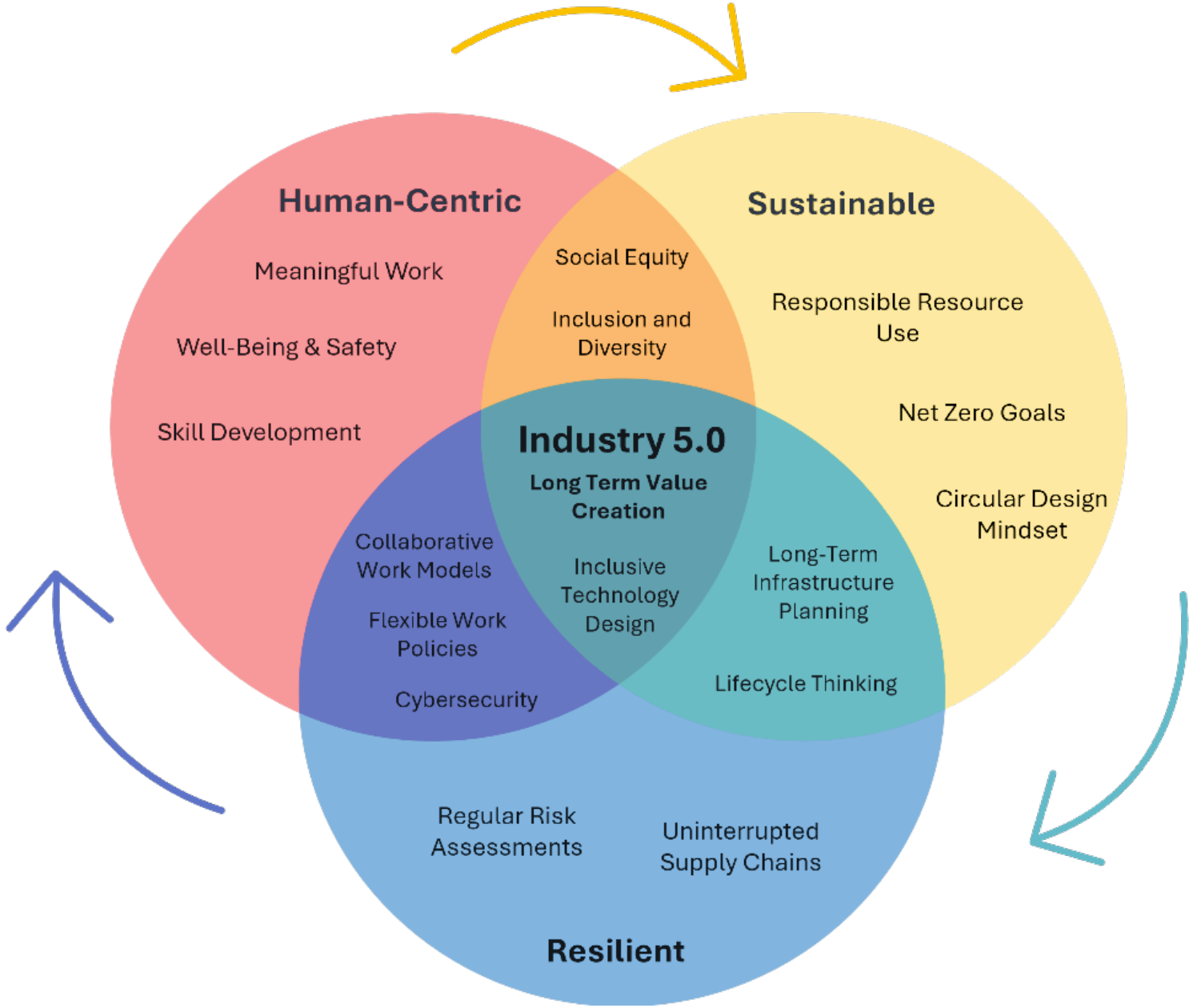
- Resilient Value Chains
- Flexible Business Processes
- Create Adaptable Production Capacity
- Create an Adaptable Workforce

Industry 5.0

Industry 5.0

Interrelated Values

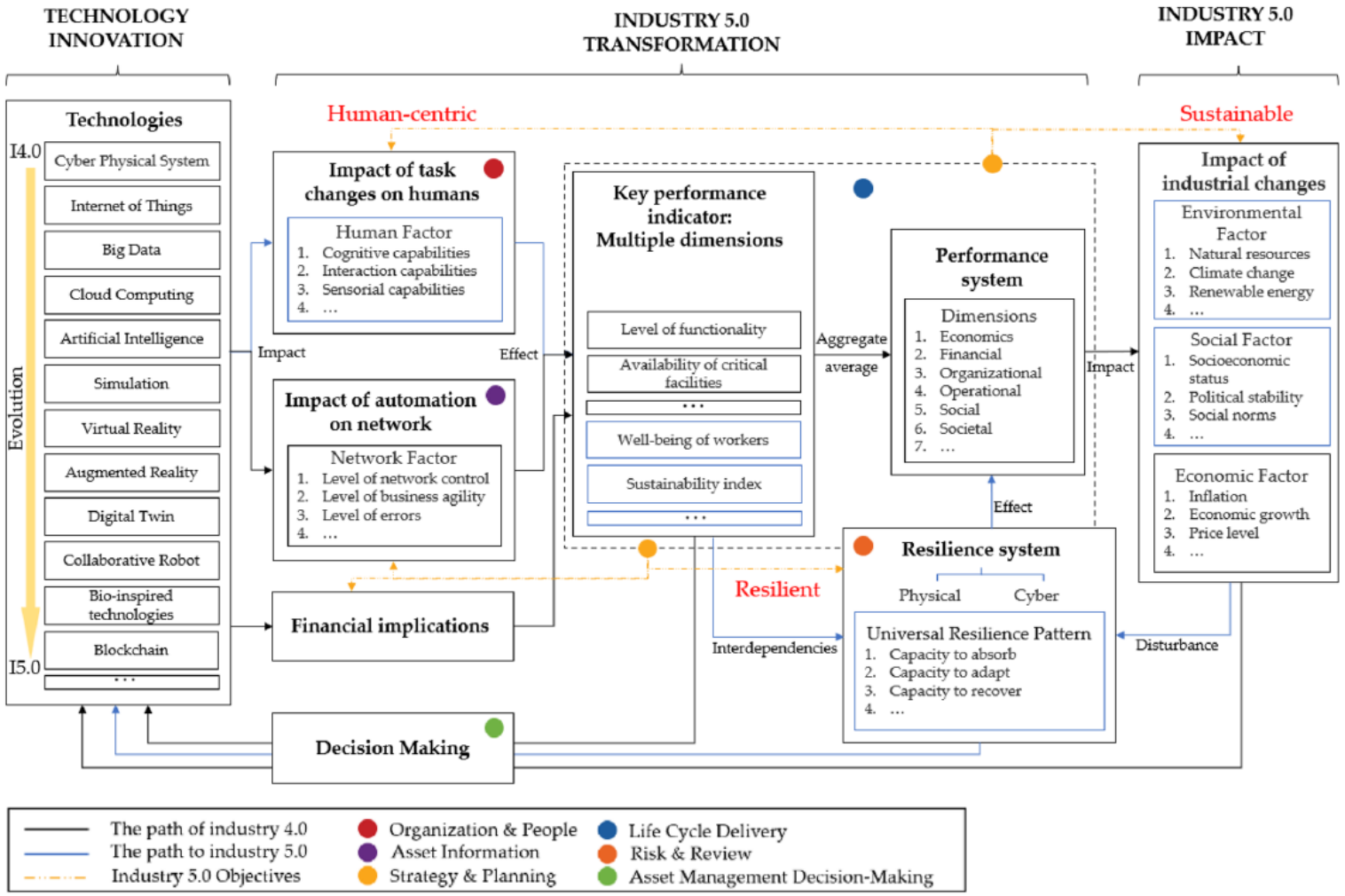
Reinforcing One Another



[19]

Industry 5.0

A Design Model for human-centred, sustainable and resilient systems



[17]

Framework for making strategic decisions related to technology development and implementation in asset management, targeting alignment with Industry 5.0 goals. The research examines the effects of technological innovation on industrial evolution across environmental, social, and economic dimensions.

Additionally, it outlines key areas such as organization and people, asset information, strategy and planning, life cycle delivery, and risk and review.

Industry 5.0

Value Model for Industry 5.0

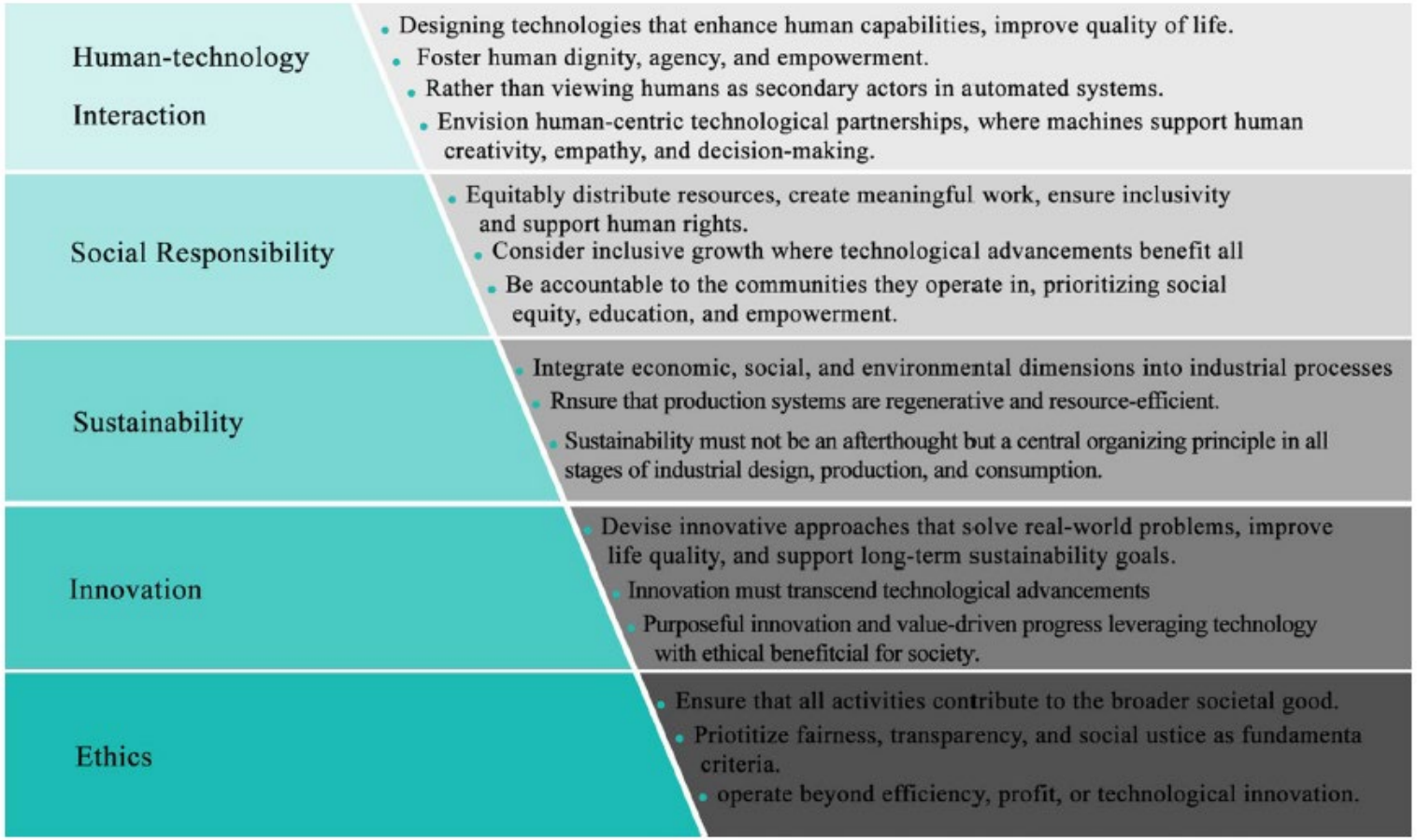


Fig. 13 Value conceptual model for Industry 5.0 (Source: authors)

[20]

This study introduces a conceptual model for Industry 5.0 that integrates human-centric, ethical, and technological factors. **It connects key elements such as ethics, sustainability, innovation, and social responsibility to create a framework that aligns technological advancements with societal and environmental goals.**

The model emphasizes a balanced approach to value creation, moving beyond the efficiency focus of Industry 4.0 and guiding industrial practices toward a more human-centered future.

Industry 5.0

Impacts

- Minimizing the Environmental Impact of Manufacturing
- Breaking Down Silos for Unified and Coordinated Action
- Encouraging Cross-Industry Collaboration
- Prioritizing Industrial Upcycling and Repurposing
- Building a Wasteless World for Everyone

[Michael Rada - https://www.slideshare.net/slideshow/industry-5-0-power-of-industrial-evolution/271750123?from_search=5#1]

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