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# D1.1 Conceptual framework of Industry 5.0 to study workforce skills.

**WP1 Understanding of the concept of Industry 5.0.**

**Deliverable 1.1**
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## List of abbreviations.

| | |
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| BRIDGES | Bridging Risks to an Inclusive Digital and Green future by Enhancing workforce Skills for industry 5.0 |
| I4.0 | Industry 4.0 |
| I5.0 | Industry 5.0 |
| KSA | Knowledge, Skills and Abilities |
| STS | Socio-Technical Systems |
| WP(s) | Work Package(s) |

## Contents

# Executive Summary.


The research note “Conceptual framework of Industry 5.0 to study workforce skills” (D1.1) is a guide for the **Bridges 5.0** project. A theoretical and conceptual framework is developed, providing insights to understand workforce skills for Industry 5.0.

Industry 5.0 builds upon Industry 4.0 and tries to improve the technological achievements of Industry 4.0. But Industry 4.0 is seen as too ‘technologically deterministic’. Therefore, Industry 5.0 brings a new perspective on technology development and organisational behaviour in the industry. Companies need to focus on human-centricity, sustainability and resilience. This means that societal values are central to Industry 5.0. Industry 5.0 is new but already embedded in EU policy and needs to find a place at the national level, especially at the level of companies and work organisations.

Industry 5.0 is a complex concept with many dimensions, which makes it difficult to define precisely. It is not our intention to make an all-encompassing analysis of Industry 5.0 dimensions. Instead, this research note focuses on workforce skills within Industry 5.0. In this context, Industry 5.0 has multiple goals (i.e. human-centricity, sustainability and resilience) and applied to multiple levels in the industrial ecosystem (society, industry level, organisations, workplaces, jobs) and is directed at different target groups (managers, employees, job seekers, students).

By first studying the dimensions independent from each other and second studying the interactions between these dimensions, it is possible to translate Industry 5.0 into skill requirements. The focus is on requirements for companies and their policy and strategy and what human-centricity, sustainability, and resilience mean for them. Subsequently, this demands a translation into needed workforce skills. The report provides guidelines for this exercise at a general level, which means that these guidelines have to be tailored and operationalised for specific applications and implementations in practical interventions at the company level and for research design and data analysis.

The interaction between Industry 5.0 goals and the target groups provides requirements for workers, company policies and other societal actors (such as educational institutes). This research note provides a first overview of what these requirements are.

The interaction between ecosystem levels and the target groups provides the requirements needed for Industry 5.0 workforce skills. These skilling requirements will be further developed and tested throughout the **Bridges 5.0** project. As such, this research note is a ‘moment in time’ of the conceptual framework that will continue to evolve.

# 1. Introduction.

## 1.1 Objective of this research note.

The Horizon Europe **Bridges 5.0** (later Bridges 5.0) project focuses on workforce skills in Industry 5.0. For the concept of Industry 5.0 itself, we direct readers to the primary documents developed by the European Commission ( 2021b; also Mller, 2021).[1] The European Commission sees the concept of Industry 5.0 as open and evolving, requiring the input of many stakeholders. In the context of the digital transformation, the core of Industry 5.0 is to ensure that industry achieves societal goals beyond jobs and productivity to become a resilient and sustainable provider of prosperity fort EU citizens. The concept aims to change company behaviour so that production respects the boundaries of our planet and places and puts the well-being of workers at the centre of the production process (Breque et al., 2021, p.14). It concerns both current internal policies as well as future investments. According to the EU's policy brief, "this wider purpose constitutes three core pillars: **human-centricity, sustainability** and **resilience**" (Breque et al., 2021). The **Bridges 5.0** project addresses these purposes in relation to workforce skills.

The objective of the underlying research note is to provide a theoretical and conceptual framework for developing solutions for workforce skills required in Industry 5.0.

## 1.2 Linking the framework to Bridges work packages.

The framework and concepts developed in this research note need to deliver guidance for the different work packages in the project. However, this research note is only a starting point, and further consensus on the framework and concept will be developed over time. **Bridges 5.0** consists of very different tasks:

- to assess the **current situation** with technology and skills for four target groups (managers, employed, students, job seekers); to **combine information from several data sources** that cover the topics of emerging technologies, forms of work organisation, workplace and social innovation, skill utilisation and development, labour market outcomes; to **test and improve** existing training interventions;
- to open up **a future-oriented perspective** on the debate **around skill needs** by combining **forecasting and foresighting methods.** We will use innovative methodologies to connect web-scraped data of vacancies and organisational-level documents to identify emerging occupations and the renewal of tasks and skills; to monitor technologically related changes in skills' demand to improve existing taxonomies; EU-wide assessments and in-depth analysis of specific sectoral regional and institutional settings will be undertaken, connecting to OECD and CEDEFOP as well as national Industry 5.0 initiatives and networks. Different methodologies will provide predictions based on projections and expert assessments in foresight workshops to understand future skill needs, skill shifts by industry, and what skills are not automatable.

For these purposes, the concept of Industry 5.0 must be evaluated on its measurability and assessed what (new) operationalisations and constructs are needed to analyse current and future data.

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[1] See also: https://research-and-innovation.ec.europa.eu/research-area/industrial-research-and-innovation/industry-50_en

## 1.3 Methodology.

To develop the framework and concepts, this report builds on a combination of methods.

A **literature search** related to Industry 5.0 was undertaken focused on scientific and policy literature. Some 500 publications were found that discuss Industry 5.0 as a concept (up to 2022). However, most of the literature does not offer empirical evidence for Industry 4.0 and 5.0 practices but is typically based on opinion and prescription. The glossary (in the Annexe) leans on recent and authoritative publications. The literature was not been extensively reviewed for this document.

A **conceptual discussion** was managed within the **Bridges 5.0** team. The expertise within the team helped to develop a plausible understanding of Industry 5.0, its pillars and their relationships. Following this discussion, the main distinction from Industry 4.0 is the inclusion of goals that are not just technological or economic but achieve goals that put people central, enable businesses to anticipate and respond to disruptions, and ensure a society's durable well-being and welfare. Industry 5.0 thus stresses a human-centred view, a 'humanised philosophy' as we see it (Oeij et al., 2019), with inclusive growth (Warhurst & Dhondt, 2023) as a normative-guiding principle.

**Practitioners and companies** were engaged to discuss with the **Bridges 5.0** team how they perceive the relevance of Industry 5.0 and its essential pillars: human-centricity, resilience and sustainability. These discussions were part of meetings of various work packages (notably in WP5 and 6 and meetings with the stakeholders and company boards). Several of these companies are involved in digital interventions (teaching and learning factories and implementing innovations) and could inform us how they enhanced the feasibility of implementing Industry 5.0's key pillars.

The results of these different methods are included in this report.

## 1.4 How to read this research note.

This research note is a first step in the **Bridges 5.0** project. It will serve as a 'living document' throughout the project, even after its first deadline, at which point this present version has been finalised. To provide a theoretical and conceptual framework to develop solutions for workforce skills in Industry 5.0, **three steps** are undertaken:

- Chapter 2 explores the Industry 5.0 concept and defines the multidimensional framework that allows to explore workforce skills. This requires an understanding of how Industry 4.0 came into existence and how Industry 5.0 complements Industry 4.0 practices. Industry 5.0's three primary goals –human-centric, resilient and sustainable – are described as well as the different ecosystem levels that these goals cover and the target groups of the current and future workforce for which the skills are relevant.
- Chapter 3 focuses on the core pillars of Industry 5.0's workforce skills. For each component of Industry 5.0, a first assessment is given for what kind of workforce skills may be needed.
- Chapter 4 deals with the skilling efforts needed to achieve the required changes. The chapter puts the core interventions developed in the project into perspective.
- The last chapter, Chapter 5, indicates where the project stands at the end of its first year (December 2023).

To keep the note as concise as possible, additional information can be found in the annexes, which contain:

- A glossary of terms.
- The role of social innovation.

- An approach for the assessment of the state of Industry 5.0 at the company level and (re)design its Industry 5.0 impacts.

# 2. Unravelling the Industry 5.0 concept.

## 2.1 Scope.

It is important to note that Industry 5.0 represents a value statement from the European Commission in the context of the digital technology transition. It offers a vison for the future of the European economy and society. With Industry 5.0 policy, the EU recognises “the power of industry to achieve societal goals beyond jobs and growth to become a resilient provider or prosperity, by making production respect the boundaries of our planet and placing the wellbeing of the industry workers at the centre of the production process.” (European Commission, 2021b, p. 3). This marks a clear difference from the previous industrial transitions up to Industry 4.0 that, were primarily technology driven. As such, the concept of Industry 5.0 is an open and evolving concept. In this sense, Industry 5.0 can be seen as a ‘sensitizing concept’. Blumer (1954, p.7) contrasted the term of sensitising concept with a definitive concept.

> *“A sensitizing concept lacks such specification of attributes or benchmarks, and consequently it does not enable the user to move directly to the instance and its relevant content. Instead, it gives the user a general sense of reference and guidance in approaching empirical instances. Whereas definitive concepts provide prescriptions of what to see, sensitizing concepts merely suggest directions along which to look.”*

As a sensitising concept, Industry 5.0 help identify the main features of what companies and other actors should do in practice. A glossary of terms is included in **Annexe 1**.

As a sensitising concept, it is the start of research. For this project, we limit the scope of Industry 5.0 to the development of workforce skills. However, even with this limitation, Industry 5.0 remains a multidimensional concept in which its three pillars (human-centricity, sustainability and resilience) touch very different realities of the individual worker and workplace, organisational policies and actions, and the societal level. The three pillars[2] are sure to also create dilemmas as they may not (directly) be seen as cost-effective or concerning which pillar should be considered to be more critical when it comes to making choices. The three pillars interact and co-determine each other, which requires a complexity perspective. In unravelling the content of this concept, we start with understanding Industry 5.0 as a multidimensional concept. We position the content in the context of the policy change from Industry 4.0 to Industry 5.0. Then we need to clarify how the concept works at different ecosystem levels and what it means for several specific target groups: (current) workers, management and job seekers, and students as the next generation of the workforce. If Industry 5.0 is about ‘behavioural change’ at the company level (i.e. change of organisational practices), this touches on decisions and behaviours made by workers, managers, job seekers and students.

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[2] This report sometimes uses ‘pillars’, ‘elements’ and ‘goals’ interchangeably when referring to the three pillars of Industry 5.0.

## 2.2 A multidimensional concept.

Industry 5.0 will be interpreted as a multidimensional concept (see Figure 1). In relation to workforce skills, we identify three main dimensions that will be explored separately in the following paragraphs. These three dimensions are:

- Industry 5.0's main pillars or societal goals: human-centric, sustainable, and resilient (Section 2.4);
- the ecosystem's different levels: workplace, organisation, industry, society (Section 2.5)
- the different target groups: students, job seekers, workers, managers/engineers (Section 2.6).

Within each of these dimension interactions exist. These interactions can be positive where interventions have a coherent effect, or negative where the effect lacks coherence with respect to choices made about human-centricity, sustainability and resilience. The EU's policy brief does not provide guidelines on how to tackle these dilemmas nor does it provide guidelines on which pillar should prevail above the others. This stresses the importance of **Bridges 5.0** to identify workforce skills that allow those involved to address the issues.

At this stage the exact interactions are unknown and unpredictable. It suffices to state that we expect considerable interactions, but the nature and extent of these interactions will need thorough analysis and has to be subject to research within the present but also future projects.

The interactions *between* the dimensions tell something about the (process of) implementation and each interaction is different in its content and outcomes, and thus lead to different skills requirements.

Figure 1 shows how we connect the different dimensions:

- ***Solutions*** form the connection between Industry 5.0's goals (i.e. pillars) and the different ecosystem levels. The connection between organisational level and sustainability is the solution for, e.g., how does an organisation adopt a circular production process?
- ***Skills*** (the skills that are needed) form the connection between the Industry 5.0 goals and the target groups: e.g., which skills do managers need for improving the sustainability of an organisation and society?
- ***Skilling*** (the process of acquiring skills) forms the last connection: between the target groups and the ecosystem levels. The skilling of the different target groups will not occur in one place, instead, each part of the ecosystem will have its own responsibility of skilling the (future) workforce for Industry 5.0.

Since the **Bridges 5.0** project concentrates on workforce skills, this report focuses on the three main Industry 5.0 goals (pillars) and the connection with workforce skills (Chapter 3) and the connection with skilling (Chapter 4). The connection and complex interactions between ecosystem levels and pillars is not part of this report.

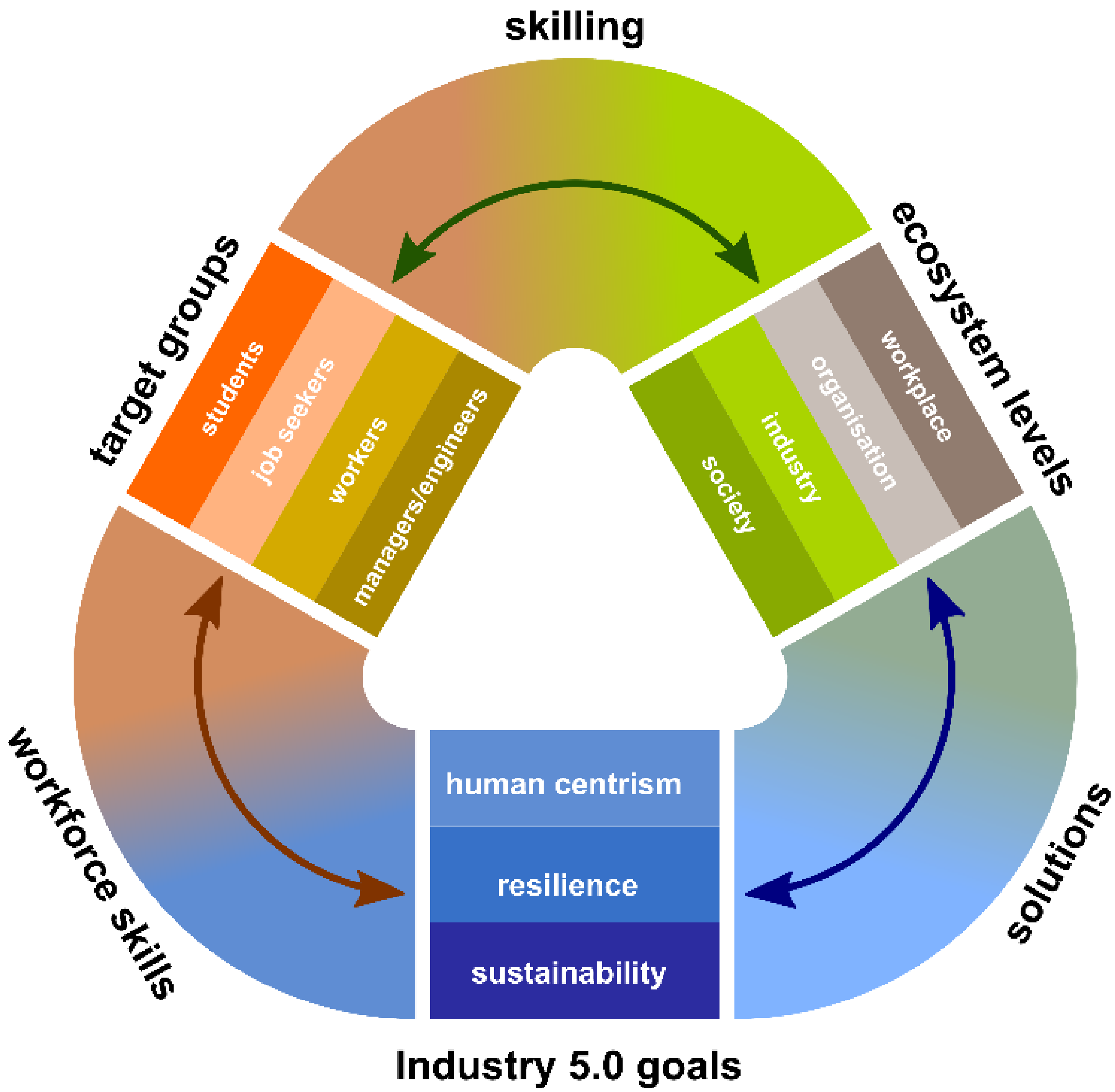


*Figure 1: Framework model for workforce skills in Industry 5.0*

## 2.3 From Industry 4.0 to Industry 5.0.

### 2.3.1 Twenty-first Century technological transformation and the emergence of Industry 4.0.

Industry 4.0 was developed in Germany as a new way of doing industrialisation in the context of wider technological transformation. It was a national industrial strategy to ensure that German high-tech manufacturing was 'fit for the future' (Kagermann et al., 2013; European Commission, 2017)[3]. It rested on the combined use of new digital technology such as artificial

[3] The assessment in many publications that the I4.0 concept is merely technology-centered is, however, rather short-sighted. On the one hand, I4.0 was indeed understood as a far reaching digitalisation project from the outset, sometimes

intelligence (AI), advanced automation and robotics, and big data (Davies, 2015). The outcome is the creation of what is sometimes called 'smart factories' that use the new digital technologies to integrate the whole production system. Moreover, the same digital technology enables the linking of this production to upstream activities (how goods are produced and supplied) and downstream activities (how goods are consumed). This digitally integrated system was lauded for offering enhanced efficiency and raising productivity by increasing production flexibility, reducing production times, and increasing product quality and customisation. It also provides customers the opportunity to customise their products, which can then be quickly and cheaply produced. As such, it is not only production but operations across the whole value chain that become integrated, from product design to delivery (Davies, 2015).

The concept of Industry 4.0 soon spread to other countries and crossed sectors into services. The European Commission noted that Industry 4.0 was becoming mainstreamed into industrial policies and could be considered as a model to follow for many countries (European Commission, 2017).

As with any industrial policy, its translation into practice is crucial. Despite becoming rapidly salient in policy and public debate and becoming the subject of scientific research, finding evidence of Industry 4.0's adoption by companies is complex. There are three reasons for this difficulty. The first is that, despite its popularity as a strategic lens, Industry 4.0 lacks an agreed definition and how it practically manifests in organisations is unclear (Davies, 2015). Second, given the lack of definition, it is impossible to measure the existence of Industry 4.0 as practice so that there is also an absence of agreed indicators. Moreover, even if a set of agreed indicators existed, a third problem exists with the lack of an EU-wide dataset that might capture data on those indicators (Greenan & Napolitano, 2022).

Past evidence suggests that implementing new technology while focusing on the technology will likely not deliver its promise of enhanced efficacy and productivity. Socio-technical systems theory (STS) emerged in the late 1940s because of this issue (Guest, 2022). STS led to a school of thought that sought a countering middle way between two existing schools of thought - scientific management and human relations. It wanted to lessen the emphasis on efficiency at the expense of human needs but thought that the pendulum had swung too far towards over-emphasising the human side of organisations (Perrow, 1973). The insight of the STS researchers was the need to optimise both the technical and social at the same time and treat them as an integrated system. As Guest explains, 'This approach might involve some compromises but promised an improved method of work design with the potential for superior performance and higher work-team satisfaction' (2022). There have been calls recently for a new STS to redress the techno-centrism of Industry 4.0 and help address its potential implementation and delivery limitations. What is needed, says Avis (2018), is a renewed STS based on technology and social relations mutually 'co-constituting' the development of the 4th Industrial Revolution.

### 2.3.2 Positioning Industry 5.0.

There are different views on the relationship between Industry 5.0 and Industry 4.0. On the one hand, it is suggested to be a deepening of Industry 4.0 (European Commission, 2021b).

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overlooking the human and social aspects of technology implementation (Howaldt et al., 2017). On the other hand, however, it was also emphasized that I4.0 had to be understood as a socio-technical system (Kagermann et al., 2013). It was also generally accepted that technology must serve, not substitute or subordinate human labour (for example in Germany). In the context of I4.0, this view was initially formulated and practised largely without reference to the concept of social innovation, which was introduced later (see Annexe 2).

The objective is to continue the digital transformation of industry. This view promoted by DG RTD is also meant to extend Industry 4.0 into the European strategy of industrial greening and sustainability by adding human- and socio-centredness (Müller, 2021). Industry 5.0 is offered as a solution to making Industry 4.0 successful. On the other hand, its treatment of the technology within the digital transformation is different. As a response to accusations that Industry 4.0 was technologically deterministic, technology is now recognised to be socially constructed and must serve, not substitute or subordinate human labour. It also adds two new elements to the industrial strategy – sustainability and resilience as responses to the climate crisis and recent economic shocks respectively. Therefore, Industry 5.0 offers a twist to, not just a continuation of, Industry 4.0.

It should be noted that whilst the language of Industry 5.0 remains firmly rooted in 'industry', it applies to manufacturing and services. The EU recognises this via the European industry standard classification system, NACE, which conceives of both sectors comprising a number of 'industries'.

### 2.3.3 How to achieve the goals of Industry 5.0.

As with Industry 4.0, the key tasks is to translate Industry 5.0 from policy into practice (Warhurst & Dhondt, 2023). Whilst the conceptualisation of Industry 5.0 addresses the techno-centrism of Industry 4.0, the three other problems with Industry 4.0 listed above continue with Industry 5.0. If Industry 5.0 is to succeed where Industry 4.0 has struggled, these three problems need to be addressed.

The first issue is that more work needs to be done on the characterisation of Industry 5.0 at the organisational level. Unlike its predecessor, Industry 4.0, there is a broad definition of Industry 5.0 (Breque et al., 2021). However, this definition operates at a high level – the industry level, or even societal level – and is abstract, thus lacking operationalizable detail. In order to become operational, it needs first) the identification of those company practices that are particular to Industry 5.0, and second) the development of actionable procedures/strategies to translate I5.0 elements to workplaces.

The second issue is that once we know what Industry 5.0 ought to look like within workplaces, there need to be industrial policies for organisations to encourage and support them in their adoption. This includes guidelines for companies and policymakers about tackling the dilemmas inevitably involved in aiming for Industry 5.0: short-term versus long-term thinking, and investment decisions. Developing such policies and practices concerning skills is a crucial function of **Bridges 5.0**. As mentioned above, the project will render the skills needed to make effective choices towards and in Industry 5.0.

The third task is to develop indicators and measurement, hence the means by which to measure the progress of organisations in adopting Industry 5.0. This task requires the development of an appropriate dataset that captures organisational adoption within the European Union. This, again, requires setting a set of characteristics defining an organisation's adoption of the separate elements of Industry 5.0 and setting baseline configurations of human-centricity, sustainability and resilience for a company to be considered as 'Industry 5.0'. Again, **Bridges 5.0** is attempting to undertake this task.

In short, what is needed to help ensure its successful translation from policy into practice is a precise definition, with indicators and a supportive dataset that enable its implementation, operation and outcomes to be both firstly supported practically within companies and then, secondly, measured and evaluated.

Achieving this goal requires changes in **companies' practices,** in the **training and education system,** and a **new coordination** between companies and training and education providers.

**Companies** largely underperform in terms of creating motivating workplaces in the context of new technology for the following reasons:

- one-third of companies experience strong internal resistance from employees to new technology (Breque et al., 2021; European Commission, 2021a);
- technology is often perceived as exogenous; employees and trade unions have insufficient opportunities to influence their implementation, adoption and uses (Cirillo et al., 2020);
- unintendedly, by introducing new technologies, companies generate more inequality between age groups, genders, educational levels, types of contracts, and other insiders and outsiders. This indicates that the social values connected to human-centricity are not part and parcel of most companies (Howaldt et al., 2017; Parker & Grote, 2020).
- lastly, companies may have insufficient knowledge of how to create motivating workplaces and/or the link between such workplaces and organisational performance outcomes that are beneficial for all parties (Fortune, August 2019; Nonaka & Takeuchi, 2021).

The **training and education system** is also deficient:

- it lacks the means to stay up-to-date, and the training methods are too far removed from companies' demand (Crouch, 2006; Pittich et al., 2020);
- it is geared toward delivering qualifications but new technologies and the greening of industry can make those qualifications quickly obsolete or at least in need of refreshing/updating (Cardenas Rubio et al., 2022);
- the return on investments in technical education is too low: barely half of the technically educated people remain in technical sectors (DTI, 2015; Verhaest et al., 2017);
- companies have an insufficient understanding of learning in the workplace and during a working career: adult learning participation and strategies (workplace learning) are insufficiently used (OECD, 2020a).

**Bridges 5.0** addresses the company practices and the skilling initiatives in the framework of Industry 5.0. The reasoning has important consequences for the research that is developed in this project. The concept puts company policies and practices at the centre of the research: we need to identify the right company policies that represent Industry 5.0. This means that workforce policies and workforce skills are a result of such company policies and practices, and there is a need, addressed empirically by **Bridges 5.0** to understand what skills are needed to support Industry 5.0.

## 2.4 Three essential pillars of Industry 5.0: human centrism, sustainability and resilience.

With Industry 5.0, the EU seeks to address significant societal challenges through companies. As the policy brief states: "For industry to become the provider of true prosperity, the definition of its true purpose must include social, environmental and societal considerations" (Breque et al., 2021, p. 13). This broader purpose constitutes three core pillars: human-centricity, sustainability and resilience". We now unpack each of these pillars.

### 2.4.1 Human centrism.

Worried about predicted massive job losses as a consequence of the clever robots substituting human labour (Frey & Osborne, 2017), policymakers began to reflect more critically on the potential human costs of the digital transformation of industry, leading to a call for a new industrial policy that places humans at its centre. This call originated from the German Federal Ministry of Labour and Social Affairs (2017) and transmuted into a call by the European Commission for a new Industry 5.0 in which ‘industry needs to consider societal constraints, aiming not to leave anyone behind’. The key role for technology is to ‘serve people (…) placing the well-being of the industry worker at the centre of the production process’ (Breque et al., 2021, p. 14). This new policy has a number of implications pertaining to safe and beneficial working environments, a respect for human rights and workers’ skill needs, according to Breque et al., This new Industry 5.0 is again intended to improve efficiency and productivity but this time so that society, companies and their employees benefit from the digital transformation.

Industry 5.0 can be seen as creating **a new technology context for companies**. Human-centricity covers two core ideas: first, that technology development, introduction and application should be **human-centred** and, second, that technology users and designers should consider the **social context**:

**Human-centred approach**

A human-centred approach to technology and work requires technology to be developed in such a way that it helps humans. For example, Welfare et al., (2019) identified several ways robots could help reduce negative work attributes and enhance positive ones, such as reducing work interruptions and cultivating physical and psychological well-being. With these perspectives, engineering sciences are given the task of adapting technology. These authors see the solution as giving Industry 4.0 a new direction for investments and technology development. Other researchers discuss the conditions under which Industry 5.0 can succeed. Besides direct benefits for humans, product customisation and technological upgrading, challenges can only be met through human involvement (Kumar et al., 2021). They call for technological progress led by human empowerment. But this is demanding in terms of human capital (Doyle Kent & Kopacek, 2021). An innovative education system where training takes place in the workplace is required. Nonaka and Takeuchi (2021) further stress the need for a “humanising” company strategy. Thus, for example, when the machines malfunction, humans need to intervene using their problem-identifying and solving skills. Hence, humans should be at the centre of company strategies, driving future-making with the help of digital-led automation. The reward to the company is resilience, longevity, and sustainability, a statement which is in line with all three Industry 5.0 goals. Several ISO-standards reflect this thinking (Totterdill, Krause & Dhondt, 2023).

**Additional socio-centred approach**

In developing human-centricity it is important to go beyond technological determinism (Hirvonen & Breen, 2020) and the needs of workers as individuals. It is also important to recognise social context and the interactions amongst workers and between workers and managers and other organisational actors (Guest et al., 2022), especially if skills needs are to be identified (Moss and Tilly, 2001). Organisations are social entities comprising different types of actors with different interests, experiences and expectations. The adoption of technology and the organisation of work are influenced by social and organisational choices (Acemoglu & Johnson, 2023). The socio-centric approach needs to be added to traditional views of human centred design, thereby going beyond (individualised) human-centric workplaces, and stressing the social function of cooperation and collaboration of humans. Human centrism involving both the individual and social approach links workplace, organisational, industry and societal levels. Only a couple of observers see a need to consider the organisational context for human-centric policies to succeed. Reiman et al., (2021) conducted a review to describe the state-of-the-art human factors/ergonomics research related to the Industry 4.0 context in manufacturing. They formulate an organisation-level maturity model to optimise overall socio-technical work system performance to cope with rapid technological development in manufacturing. Scientists expect positive effects from Industry 5.0. Nahavandi (2019) argues that it will create more jobs than it takes away. The question is what type of jobs these will be. Industry 5.0 requires new organisational policies: can workplace innovation (Howaldt et al., 2017; Oeij, Dhondt & McMurray, 2023) be a solution? Evidence shows that some 20% of companies in Europe are investing in 'high investment, high involvement' strategies (Eurofound & Cedefop, 2020).

### 2.4.2 Sustainability.

In the context of the climate crisis, the European Commission initiated the Green Deal with the goal of being the first climate-neutral continent. To achieve this goal, a massive reduction in energy consumption and use of natural resources is required, which requires heavy involvement of European industry. Additionally, the EU encourages a circular economy where industry re-uses, re-purposes and recycles products and resources.

Sustainability has strong ties with digital technologies, with these technologies able to support production that might save resources and reduce costs (Breque et al., 2021, p.14). One example here, and which links to both Industry 4.0 and Industry 5.0 is smart specialisation.[4] The importance of this development topic has increased steadily in the manufacturing sector for many different reasons (e.g. environmental concerns, diminishing non-renewable resources, stricter legislation and inflated energy costs and, consumer preferences for example.). Overall, Industry 5.0 proposes production that emphasises the integration of human expertise with advanced technologies such as robotics, artificial intelligence and the Internet of Things (IoT) to create more circular and sustainable production processes with strong consideration of resource use in a long term.

Taking into account life-cycle perspectives will mean doing better with less by optimising the relationship between product output and resource input and the EU advocates developing sustainability targets for measuring progress through a high-level expert group.[5]

### 2.4.3 Resilience.

In the context of the global financial crisis and later COVID-19 pandemic and now the war in the Ukraine, the EU wants to be better prepared to withstand major disruptions. These disruptive events have revealed the vulnerabilities in the value and supply chains of companies operating in Europe. The EU wants increased preparedness from companies so that they can deal with these disruptions. Industry plays a key role in providing the critical infrastructure, such as healthcare and security, that is needed in times of crisis. Under stable circumstances, the focus on efficiency leads to cost reductions, often at the expense of creating vulnerabilities in the supply network and production. Therefore, industrial resilience is key. Breque et al., (2021) stress the need for robust industrial production within Industry 5.0. The focus for Breque et al., (2021) is having resilient value chains and resilient production capacity and business processes.

Different research communities differ in their understanding of the concept of resilience but there are *commonalities*. In **Bridges 5.0**, we consider resilience from a systemic perspective on the level of firms and industries. This entails that the target is the resilient (sub-) system (firm, sector, industry), which has repercussions on the resilience skills of the workforce.

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[4] European Commission's Smart Specialisation Platform

[5] https://research-and-innovation.ec.europa.eu/strategy/support-policy-making/shaping-eu-research-and-innovation-policy/esir_en

Resilience requires better anticipation of what will happen and strategic intervention to support the strategic changes:

- Anticipation and self-organisation: monitoring current risks (Breque et al., 2021) and understanding a complex world. Organisations that are too rigid and hierarchical are likely to miss opportunities.
- Strategic management, dynamic capabilities and strategic redundancy: 'the firm's ability to integrate, build and reconfigure internal and external competencies to address rapidly changing environments' (Teece et al., 1997, p.516). Strategic management skills, according to Vogel and Güttel (2012), comprise strategic learning and change, i.e. skills and learning capabilities applied to strategic management with the aim of rent-seeking and increasing firm performance in a context of change. Skills are framed as capabilities and are increasingly dynamic, co-evolving with organisational phenomena like firm governance structures, open innovation, ecosystems and a view on the central role of stakeholders.

A particular type of resilient organisation is 'high-reliability organisations', which have internalised the capability to anticipate, respond and recover in the case of disruptive events (Dwyer et al., 2023).

## 2.5 Ecosystem levels.

### 2.5.1 Work/worker level.

Industry 5.0 differs from Industry 4.0 because of its explicit attention to the worker and work. Human-centricity is about improving labour market access, employment security within the labour market and the quality of jobs in that labour market. In the end it is also about creating opportunities for job seekers and students. As a result of the improved conditions, workers can do their jobs better, which benefits the organisation and the industry (Erikson et al., 2023). Additionally, those without work could benefit from easier access to work. Resilience and sustainability are about behavioural change and affecting all target groups of the project. They all need to understand how they can make their organisation more sustainable through their work and their company practices more circular, more robust and more resilient. Concepts at the individual level, such as the resilient worker and sustainable employability, are included in the concept of human-centricity[6].

### 2.5.2 Organisational level.

The organisational level reflects the responsibilities of management and the collective of workers. Resilience, as it is currently conceived in Industry 5.0, primarily concerns the organisational level. It aims to ensure the robustness of company production in the face of economic disruptions and shocks by strengthening critical business infrastructure. This resilience at the organisational level transcends to the industry and societal level as organisations that succeed in remaining operational significantly improve a society's ability to remain functional in times of crises. Organisations should incorporate human-centricity, resilience, and sustainability into their values and business models and expand their conventional economic indexes (such as capitalisation, market penetration, revenue, and profit) with additional Industry 5.0 indicators (European Commission, 2021b). As a result, new business models might be adopted that, for example, aim for circularity in the provision of goods and services.

[6] N.B. Under discussion is if the term job level would be more appropriate than workplace.

Human-centricity is a concept that should be adopted across the whole organisation. It requires acknowledging the role a company has in its surroundings – human society, instead of viewing society as a resource for workers to achieve isolated company goals. A human-centric approach views workers as assets in which the company should invest, for example, training and education. Workers, in return, share a larger responsibility with respect to participating in the company's Industry 5.0 objectives.

All these changes require that the workforce, at all levels, acquire different skills from their present ones. Typically, organisations rather than governments are more aware of these needs and can more quickly respond to changing skill demands. As such, organisations and their managers, should have a greater role in identifying required skills and training for those skills.

It is important to mention that an 'organisation' is not a fixed concept. With hybrid work, platforms, networks and self-steering teams etc., organisational boundaries are evolving, becoming variously more fragmented, extended and permeable (Benkler, 2007).

### 2.5.3 Industry level.

Industries need to manage their impacts on society. All three pillars of I5.0, human centricity, sustainability and resilience have a sectoral/industry dimension because technological opportunities and constraints follow sectoral patterns. Resilience and sustainability primarily benefit the society in the long term as it decouples economic prosperity from the use of energy and resources. The direct short-term benefits at work/worker and organisational levels are less tangible and require considerable investments. These investments can only be made when certain requirements are met, for example a level playing field between competitors. This requires sectoral and societal commitment where these transitions are incentivised (example: agreeing to use zero emission vehicles in last-mile logistics). The objectives and the methods are different for each sector. Policy and standardisation at the industry level can help organisations align on the chosen approach and create a level playing field.

### 2.5.4 Society level.

A '5.0 Society' that would entail values of human-centricity, resilience and sustainability, would build institutions to support this development. Democratic institutions, broad education, inclusive growth and access to social security would be among the most salient ones. These institutions and their values and norms would nurture a culture of welfare combined with well-being for all life on the planet now and in the future. This extension across levels within the ecosystem is now new. Although difficult to manage at the time (Guest, 2022; Guest et al., 2022), there was a clear strand of thought amongst some proponents of STS thinking that there should be spillovers from the workplace into society, most obviously with workplace industrial democracy intended to bolster political democracy in society.

## 2.6 Target groups.

For **Bridges 5.0**, we have identified four target groups which, in addition to overlapping workforce skills, may each have their own specific skills requirements. The groups form the future workforce (students and job seekers), current workforce (workers) and those playing an important role in creating and managing Industry 5.0 (managers and engineers[7]).

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[7] Engineers were added after the completion of the proposal. Engineers of new technology, IT, software, etc. can have a major impact on the design of work/jobs via the design of technology, for example.[8] In general, there is a lack of focus on the developers of digital systems. Even the basic design of many systems has a strong influence on the possibilities for skill-oriented work. In other words, important decisions are made at the design level that often

The workforce will need more than just skills. Knowledge and abilities are also important. However, in this document, we refer to 'skills' to encompasses all three facets on the basis that 'skill' has become a general 'umbrella term' that now covers more than just qualifications as was previously the case when referring to skills and can now include attitudes and that being skilled requires knowledgeable practice (Grugulis et al., 2004; Thompson, 1989). These workforce skills will require different skilling approaches, directed at the different target groups and different institutions.
**Bridges 5.0** foresees a link with 'social innovation' opportunities for the four target groups. The Industry 5.0 Platform that will be developed by **Bridges 5.0** will facilitate social innovation in the learning field. The platform will also provide stakeholders and four target groups with recommendations and instruments for new learning and training systems. **Annexe 2** provides further insight into the role of social innovation in relation to Industry 5.0.

### 2.6.1 Students.

Students are those following vocational training and those in less specific education such as scientific training at universities. Through their curricula, educational institutes can have a key role in creating advocates of human-centredness, sustainability and resilience. As Industry 5.0 is a vision for the future, values, norms and culture play a large role in it.

### 2.6.2 Job seekers.

Job seekers include the short and long term unemployed, and future labour market entrants. Skilling efforts require mobility measures on the labour market. It will also require understanding from labour market institutions of what skills companies will be needing in the future.

### 2.6.3 Workers.

Workers may themselves invest in training and are increasing expected to do so, especially by government (Gambin and Hogarth, 2017). However, the major reskilling effort will be at the company with on-the-job training and other forms of non-formal training. Additionally, current employees might have unique knowledge that needs to be transferred to a new generation of workers.

### 2.6.4 Managers and engineers.

Managers *and* engineers are responsible for the decisions that lead to Industry 5.0. Traditionally, managers at different levels were responsible for the decisions that were made in an organisation. However, digital technology is becoming more pervasive within organisations. First, because decisions are now more data driven. Second, because employees increasingly rely on technology in the execution of their work. This technology will impact the job quality of their work. As such, design decisions made by engineers have a significant impact on all these aspects. Because of this, managers and engineers are selected as the key decision-makers who should adopt new skills. Both groups have a leading role in the adoption of Industry 5.0. The critical challenge for these groups is to adopt a broader perspective that comprises not only the economic factors but also human, resilience,

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do not include social criteria. This dimension is particularly relevant to the question of the conditions under which human-centred technologies can be developed and used.

and sustainability factors[8]. Engineers need to adopt new criteria in their design process. Aiming for human centrism will also require more direct input from different stakeholders by using design methods such as co-creation and ethics for innovation (Steen, 2023).

[8] In general, there is a lack of focus on the developers of digital systems. Even the basic design of many systems has a strong influence on the possibilities for skill-oriented work. In other words, important decisions are made at the design level that often do not include social criteria. This dimension is particularly relevant to the question of the conditions under which human-centred technologies can be developed and used.

# 3. Industry 5.0 and workforce skills.

Industry 5.0 requires companies to be human-centric, sustainable and resilient. The first task is identifying the workforce skills that will translate these pillars into successful company practices. There is then an additional task for **Bridges 5.0** to identify any specific skill needs required by the target groups.

## 3.1 Workforce skills – which skills and how to define.

### 3.1.1 Skills, attitudes, competences and qualifications.

How skills at work are defined and comprised is a matter of some debate. It is important to observe that **Bridges 5.0** sees occupations (and their role descriptors) as too narrow. People can have combinations of tasks that differ while having a similar position or function in name, as is recognised in the European Qualifications Framework (EQF). We therefore lean towards the methodology of the e-Competence Framework (eCF) that focuses on individual competencies (what a person has) and organisational competencies (what business processes require) (CEN et al., 2013). It thus covers the supply and demand for skills at work. Notably, the eCF definition encompasses the "demonstrated ability to apply knowledge, skills and abilities (KSA) for achieving observable results". Knowledge is the "set of know-what", skill is the "ability to carry out managerial or technical tasks" (know-how), and attitude is "cognitive and relational capacity" (p.13). Although the eCF strongly stresses IT skills, it thus deviates from the European Qualifications Framework (EQF) in that the eCF sees attitudes as broader than only "autonomy" and "responsibility" (CEN, 2014). This unbundling into component parts is important. Research on green jobs shows, for example that the skills of some occupations remain unchanged but that the knowledge component of those occupations is being greened (Cardenas Rubio et al., 2022).

Industry 5.0 requires not only changes in knowledge and skills but also in the workforce's attitudes. The eCF and EQF distinguish proficiency levels that relate to job performance, being capable in a specific knowledge or skill domain, and learning levels. Learning levels are defined through the degree of autonomy over an activity, the context complexity, and (observable) behaviours. For these levels, we refer to these frameworks. Due to the new technologies and digitalisation, there will be new 'know-how' (skills) and new 'know-what' (knowledge) required within occupations. Capturing both in classifications of green and digital jobs is important, not least because these new and changing skills and knowledge requirements will both need to be reflected in education and training system curricula as they adapt to the transition to net zero. In the United Kingdom, for example, the Standard Occupational Classification[9] is used for this purpose. When we talk about skills, a useful distinction is:

- the need for foundational skills such as literacy and basic digital skills, necessary for many jobs in the digital age;
- the need for job-specific skills necessary for a specific profession or function; this includes specific social and interactive skills (which, for example, differ for hairdressers from software programmers);
- the need for Industry 5.0 skills related to acting human-centric, resilient and sustainable.

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[9] The bundle of skills and knowledge as well as the entry qualifications of any occupation are listed in the UK's Standard Occupational Classification (SOC). A revised full SOC is published every ten years to take into account the emergence of new occupations. As a supplement to this publication the SOC now makes ad hoc minor amendments on its website to its index as new information about occupations emerge. SOC gives every occupation a descriptor and number.

In identifying workforce skills, we must go beyond the level of jobs and functions and analyse what the requirements of Industry 5.0 are at the company level. The way companies redesign their strategy and production system, in alignment with human-centricity, sustainability and resilience requirements, unveils needed skills at the level of the workforce. Aggregating these views to industry and societal levels will help us to understand how societal values can eventually be linked to skills and the underlying values of the quality of jobs and working life.

### 3.1.2 Identifying which skills are needed.

Identifying the skills needed to create and maintain an Industry 5.0 company is not easy as companies that have adopted Industry 5.0 are difficult to identify – in part, as we noted above, because it is a new development and as yet poorly defined (Warhurst and Dhondt, 2023) and in part because there is no bespoke dataset that captures digital technology adoption within companies in Europe (Greenan and Napolitano, 2022). To identify the skills that are need, two paths need to be explored as a process.

First, it is important to find companies that serve as frontrunners. E.g. several startups and existing companies exist that have built their business around values that are different from regular business with a solid cost-driven focus and only focusing on shareholder values. In these businesses, the following aspects could be identified:

1. organisational practices and structures
2. tasks associated with those practices and structures
3. these tasks' underpinning skills (i.e. their KSA, knowledge, skills and abilities)
4. indicators to capture and measure these skills

The second path is to create a realistic virtual image of an Industry 5.0 company[10]. To be able to create such an image, it is necessary to define the pillars comprising a company and how we expect these pillars to be organised and behave in an Industry 5.0 kind of way. From these behaviours ('practices') follow typical tasks and the KSAs of the workers.

Exploring both paths will also clarify a baseline profile: when do we consider a company to be Industry 5.0, and when not? A start has been made in **Annexe 3** how to assess if a company meets Industry 5.0 requirements and how to design Industry 5.0 impacts with regard to the implementation of organisational change and / or (technological) interventions.

Identifying Industry 5.0 companies in existing survey material requires another approach. The way here to move forward is to gather information about investments in technology and forms of work organisation (i.e., learning organisations) and to analyse to what extent such companies meet Industry 5.0 characteristics. This could provide insight into the types of organisational forms, the management philosophy of such companies, and the kind of workforce skills and employee voice present in such companies. As indicated, there are already ISO-norms that are meant to help companies develop human-centric practices (e.g., ISO 27500: 2016 - The Human-Centred Organisation).

In the following sections, we provide a general idea of the skills needed for each of the Industry 5.0 pillars.

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[10] Empirically and analytically, further on during the Bridges project we intend to differentiate in order to capture the broad field of companies with I5.0 solutions, such as a distinction between different types of companies with regard to characteristics such as sector and product, technology intensity, company size and qualification level. The respective qualification level in particular will largely determine the character of a learning organisation, introduction processes and, in particular, participation potential.

## 3.2 Human-centricity and workforce skills.

The human-centric aspect of Industry 5.0 “places the well-being of the worker at the centre of the production process and uses new technologies to provide prosperity beyond jobs” (Breque et al., 2021). The basis of this concept is a change in the strategic orientation of manufacturing companies and the mindset of industrial companies, mainly from profit maximisation towards increased responsibility for society and the people within the organisation (Breque et al., 2021). From the discussion above on human-centric, the following demands are put on the workforce:

- Dealing with human-centred technologies, and
- Dealing with empowerment and participation.

Human-centric workforce skills will need to cover at least these demands.

### 3.2.1 Dealing with human-centred technologies.

Human-centric technology needs to factor in that human-centredness in its design, introduction, use and outcomes. Most policy debate and research about the new digital technologies has focused on the last two issues in as much as the use of these technologies by companies has been predicted to eradicate human labour (or a discussion, see Warhurst et al., 2020).

However, technology does not only replace humans; it also augments their capabilities (Autor et al., 2020). A specific form of augmenting technologies are assistance technologies. Their purpose is to support people in their work and to make work easier. Assistance technologies enable individual need-based support directly at the workplace (Sorko & Brunnhofer, 2019), whether due to physical limitations, different levels of education, or other language skills. Such technologies offer a means to address shortages of skilled workers to an increasing number of potential workers (Sorko, 2022). Especially in industry, collaborative robots (Wallhoff et al., 2019) or augmented and mixed reality (AR/MR) solutions (McKinsey, 2022) are increasingly implemented. The latter, especially in the context of individual information provision and on-demand training. It requires the workforce to work with these technologies and support the development of technologies in the workplace. This last part requires an understanding of how to implicate the workforce in developing these technologies. A human-centric view of technology and work requires that the workforce is able to be a partner in the explainability of technology. Human-centred technologies require new competencies such as intervention and control of technology, learning from work and participation in decision-making.

### 3.2.2 Empowerment and participation.

Whereas in the past, the assumption was that technology would replace humans in manufacturing areas, the trend is now steadily tending towards a collaboration between people and technology. The influence of technology on the work design depends on the technology itself, the organisational framework in the company, and the intended areas of application of the technology. In addition, the personal attitudes of workers towards the technology also influence the usage of the technology and the quality of work results. Optimal use of technology requires the decentralisation of decision-making and empowers workers to have more autonomy in decision-making (Parker & Grote, 2020). The workforce not only needs to understand technology they work with, it needs to understand how to co-determine the shaping of Industry 5.0 workplace. Empowerment with voice, and task autonomy and participation is core to human-centric technology and work. To make this empowerment work, both workers and management need to be equipped with the right skills and tips into debates about learning organisations (Greenan et al., 2023). Thus, Industry 5.0 requires workers being empowered with task autonomy and participation, supported by appropriate management and organisational practices. A challenge in this perspective is that the workforce of companies includes not only its employees or personnel on their pay roll, but comprises of external agents as well, that can contribute to adding value to a companies' product from different positions. This extended workforce can consist of contractors, gig workers, service providers, subcontractors, complementors and others (even bots and agents in different time zones), indicating that the organisation of work is changing as well (Altman et al., 2023).

## 3.3 Resilience and Workforce Skills.

### 3.3.1 Anticipation skills.

Resilience is widely seen as the capability to anticipate external and exceptional shocks and/or crises (Fougère & Meriläinen, 2021). As we noted above, these shocks or crisis could be the COVID-19 pandemic or the Global Financial Crisis. They could also be a combination of more long-term pressures such as climate change mitigation and short-term peaks with the energy crisis due to the Ukrainian war. Resilience has an invariably positive connotation (Patel et al., 2017), seen as a collective resource and capacity, social support in a system, a coping mechanism, and a collective systemic reduction of vulnerability. However there can be tensions and trade-offs. In general, for example, there is an inherent trade-off in the strive towards resilience between efficiency and redundancy. Efficiency in the form of outsourcing, downgrading, saving resources, saving costs, streamlining structures, etc., may lead to lock-ins and rigidities that, in the face of a shock, lead to vulnerability and disruption. By contrast, redundancies are perceived as inefficient in periods of non-crisis and a short-term perspective. In the long run, acceptance of redundancies may however be an enabler of long-term flexibility and long-term efficiency. Resilience translated to skills would entail that the workforce at different levels – from management to operators – understands how to anticipate such shocks and how to develop strategies to deal with these shocks.

### 3.3.2 Understanding how to manage resilience.

In their literature review of definitions of community resilience, Patel et al., (2017) identify commonalities. These commonalities are i) local knowledge, i.e. a community understanding and being aware of its vulnerabilities; ii) networks and relationships, where positive effects can occur during or in the aftermath of a crisis when members of a group are "well-connected and form a cohesive whole" (p.7); iii) communication, to develop a shared understanding and frames, enabled through partial and overlapping networks of communication; iv) governance and leadership, with the two dimensions of infrastructure and participation; v) resources, tangible and intangible; vi) economic investment; vii) preparedness, which in some literature, e.g. (Roth et al., 2021) is termed 'anticipation', can be understood as monitoring risks, or more narrow as disaster preparation plans); viii) mental outlook, defined as the willingness to continue in the face of uncertainty. Managing resilience requires understanding how to manage these networks and resources. Resilience requires governing system security in case of shock/crisis, compensating system failure through systemic bouncing back to the state before the crisis. (see e.g. Jasiūnas et al., 2021). Resilience is also the ability to bounce forward, i.e. learn from the past, conceptualise shocks as an opportunity to evaluate options and embrace (radical) change (creative destruction) (Hynes et al., 2020; Roth et al., 2021; Schumpeter 1942). These are all very different dimensions that require new skilling approaches.

## 3.4 Sustainability and workforce skills.

To develop sustainable production systems requires coordinated efforts in many areas (product, process, technology, organisation, skills, leadership approach etc.) and along the whole value chain (Giret et al., 2015). To attain the sustainability goals, green related KSAs are needed amongst the European workforce.

### 3.4.1 Green jobs, tasks and skills.

A definition of green jobs needs to cover two components: (1) jobs in businesses that produce goods or provide services that benefit the environment or conserve resources; (2) jobs in which workers' duties involve making their establishment's production processes more environmentally friendly or use fewer natural resources (US Bureau of Labor Statistics[11]). O*NET[12] focuses on sustainable economic activities. This approach helped Cardenas Rubio et al., (2022) to identify three broad categories (or a 'taxonomy') of 'green' jobs. There is no strict division between new, green industries and traditional, non-green industries (Cardenas Rubio et al., 2022), as all industries need to contribute to sustainability targets. The transition will create new jobs as well as change existing jobs across all sectors.

Cardenas Rubio et al., (2022) see the development of three kinds of jobs:

(1) New jobs: the impact of green economy activities and technologies creates the need for unique work and worker requirements, which results in the generation of new occupations. An example is solar system technicians, who must be able not only to install new technology but also to determine how this technology can best be used on a specific site.

(2) Existing jobs with new tasks: the impact of green economy activities and technologies can result in significant changes to the work and worker requirements of existing occupations, thus requiring enhanced skills and knowledge. This impact may result in an increase in demand for these occupations. The essential purposes of the occupation remain the same but tasks, skills and knowledge have changed. An example is architects who now require knowledge about energy-efficient materials and construction as well as skills for integrating green technology into the aesthetic design of buildings.

(3) Existing jobs: the impact of green economy activities and technologies can increase employment demand for some existing occupations. However, this impact does not entail significant changes in the work and worker requirements of the occupation. An example is the increased demand for electrical power line installers and repairers related to energy efficiency and infrastructure upgrades.

Cardenas Rubio et al., (2022) developed a new green occupational definition, or a 'GreenSoc', a 'Green Standard Occupational Classification'. The GreenSoc is based on an adaption of the three types of green occupations and then applied to Labour Force Survey (LFS) data and data scraped from job vacancy websites. Analysis of web-scraped job vacancy data provides a picture of dynamics of change in 'real time' and is especially useful given that green jobs are an unfolding development within the labour market, i.e., job vacancy data can usefully capture changes in jobs as signalled by the demands from employers.

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[11] https://www.bls.gov/green/home.htm#definition

[12] O*NET is a classification of occupations that identifies and collates information on occupations in the US including their tasks, skill sets and knowledge use (https://www.onetonline.org/)

### 3.4.2 Sustainable behaviours.

The previous pillars of sustainability deal with policymaking and specific changes in tasks. However, the green transition requires significant changes in the behaviours of the workforce. Reaching net-zero emission targets requires a fundamental shift in workers' attitudes in work. The input of everyone is needed to avoid unnecessary emissions and support to change personal behaviours (for example, travel behaviour) and deal with the complicated trade-offs that will arise.

## 3.5 The way forward: research demands.

Table 1 mentions the directions in which Industry 5.0 workforce skills need to be developed. Within the **Bridges 5.0** project, the state-of-the-art in sectors and companies will be researched. By 'directions', we mean identifying ways to move towards Industry 5.0 goals. A separation is made between the efforts that are needed to create Industry 5.0 and what is needed once it is established, i.e., what it means to work in Industry 5.0. In a later stage, these directions will be translated into skills for the identified target groups[13].

The new perspective also requires a specific research approach. Figure 2 provides an overview of the demands to the Bridges 5.0 research approach. This research approach is developed in WPs 2 (survey), 3 (big data analysis), 5-6 (training programmes).

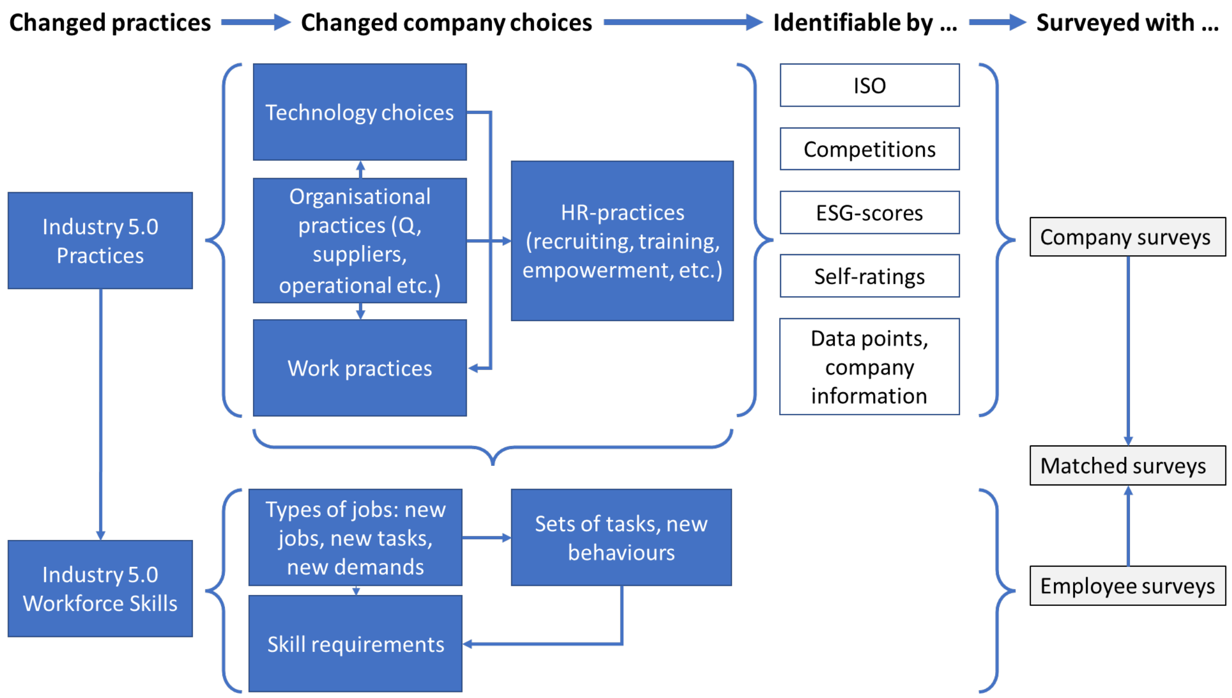


*Figure 2. Overview of requirements to the research work packages of **Bridges 5.0***

The figure identifies the main Industry 5.0 practices at the organisational and sectoral level. These practices will have an impact on the workforce skills that will be needed. These workforce skills may be already visible in these companies. Industry 5.0 practices can be understood by looking at organisational practices. These organisational practices will influence technology choices and management practices (including HR practices) and will all

[13] The learnings of WP5 and 6, where implementations in companies will be studied in 'teaching and learning factories', can be seen as test cases how this can be achieved in practice.

impact the actual work practices that can be found in companies. These changes in practices may be identified in the use of specific ISO-norms, participation in company competitions (e.g., A Great Place to Work), Environment-Social-Governance (ESG) scores that companies may achieve, self-ratings or in many information that can be collected on companies in several sources (e.g., Annual reports, websites) (see Totterdill, Krause & Dhondt, 2023). Of course, these scores may need some closer inspection because the risk of greenwashing is quite real (AFM, 2022). There are company-based surveys that map company practices (e.g., the European Company Survey administered by Eurofound).
The bottom-side of the figures maps the impacts of the company practices at the level of jobs, tasks and skills. These changes can be mapped in different employee level surveys such as the European Working Conditions Survey, also managed by EUROFOUND. Matched surveys may help to relate company practices to employee impacts.
Table 1 provides an overview of possible workplace level practices that indicate new demands on workers. The list of activities is not exhaustive, only indicative of what we may find in companies.

| | Create I5.0 | Work in I5.0 |
|---|---|---|
| **General** | ▪ Design and use digital technologies and AI systems in a way that meets Industry 5.0's three objectives<br>▪ Include human-centric, resilient and sustainable values in business models and KPIs. | ▪ Learn to and work with existing, new and complex digital technologies and AI systems. |
| **Human-centric** | ▪ Understand human-centricity<br>▪ Include basic humanised values, e.g., autonomy, voice, participation and self-fulfilment (based on evidence-based criteria of job/work design)<br>▪ Support and implement worker empowerment in decision-making processes aimed at change and daily operations<br>▪ Empower through workload optimization/ decision-making and act inclusive<br>▪ Appy a *human in command*-principle with respect to human-technology interaction<br>▪ Use human-centred design methods<br>▪ Use assistive/supporting/augmenting technologies | ▪ Demonstrate intrapreneurship and make use of being empowered<br>▪ Make use of learning opportunities (see also Resilience)<br>▪ Participate in processes related to (re) design/change<br>▪ Adopt an inclusive attitude<br>▪ Be able to communicate in participation processes (internal and external interaction)<br>Working with assistive technologies |
| **Resilient** | ▪ Assess the company's dependencies through different scenario planning and risk assessments<br>▪ Develop a resilient production process, and along the value chain<br>▪ Develop a resilient network of suppliers, partners, and customers (systemic thinking) / supply chain/value chain<br>▪ Encourage creativity, innovation, and flexibility, e.g. by providing learning opportunities for them<br>▪ Implement training and education systems that develop KSAs) knowledge, skills, abilities)<br>▪ Develop strong risk management policies and financial resilience | ▪ Understand/integrate resilience into company policies<br>▪ Engage in lifelong learning and develop the ability to adapt and to creativity<br>▪ Reflect on and respond to the resilience of the work process and analyse and solve problems at the systems level<br>▪ Manage yourself |
| **Sustainable** | ▪ Care for the environment<br>▪ Provide the knowledge for workers to do so<br>▪ Carry out environmental impact and lifecycle assessments<br>▪ Make and promote 'green choices, use green technologies, develop green tasks and design and implement circular processes | ▪ Care for the environment and act sustainably<br>▪ Understand circularity and carry out lifecycle and environmental impact assessments<br>▪ Evaluate green technologies<br>▪ Elaborate resources efficiency |

*Table 1: An overview of directions in which to develop Industry 5.0 workforce skills*

# 4. Skilling for Industry 5.0.

The last part of this section addresses the way skilling happens in practice. The interventions needed to achieve the required workforce skills will differ across the target groups and for the different goals of Industry 5.0. **Bridges 5.0** starts with existing skilling interventions. Over the course of the project, other approaches will be developed or included.

A core idea of Industry 4.0 strategies is a new relationship between industry and education and training. In most EU countries, new initiatives such as living labs, field labs and other combined public-private learning ecosystems have grown rapidly over the past decade to support the industry's transformation. Alongside these institutional changes, attempts are made to redevelop the pedagogical approaches in companies and the education and training system that develops workforce skills. Initiatives can be found at two institutional levels: new educational and training efforts at the **company level** and new agreements between the stakeholders in the educational field at the **national and regional levels**. Educational specialists contend that new competencies only succeed if action-based learning and comprehension-based learning are combined (Pittich & Tenberg, 2013). Therefore, the attention has focused in creating more practice-based learning environments. However, the assessment of outcomes and evidence of these learning factories remains limited (Nick et al., 2019; Pittich et al., 2020), mainly because of the inaccessibility of these interventions (Lensing, 2016). **Bridges 5.0** classifies the interventions with practice-based learning at the company level as **Teaching Factories**. The Teaching Factory approach is seen as an alternative in which education, research and innovation activities are integrated (Chryssolouris et al., 2016). This approach may be a more sensible way forward for the green and digitalisation transitions. Nevertheless, systematic evaluation is also lacking.

The challenge is that some transitions can be fast within some companies, with the consequence that training and education investments in schools, colleges and universities can become quickly obsolete. As Crouch (2006) has observed, some actors within the skills system, such as the state, can be very slow to recognise and adapt to workplace change. In this context, those interventions might benefit from broader public-private engagement in learning ecosystems represented by **Learning Factories.**

There is a wide variety of configurations for Learning Factories adapted to the skills needed by the different target groups (Abele, 2015). It is possible to design Learning Factories scenarios to focus on specific combinations of technologies and, at the same time, allow users to enforce situations related to Industry 5.0's aspirations for production systems that enhance human centricity, resilience and sustainability within companies' strategies (Hvidsten, 2022). Here again, a standard for skills assessment is needed.

The Digital Economy and Society Index (DESI) tracks Europe's digital performance in skilling. EU countries' progress shows that many national initiatives are striving to align vocational education and training (VET) with digitalisation (DESI, 2020). Public-private partnerships have been established alongside Industry 4.0 programmes to develop skills, especially related to science, technology, engineering and maths (STEM). Each country has a Pact for Skills (Grond et al., 2021). However the Skills Forecast of Cedefop & Eurofound (2018) warn of impending skill surpluses by 2030. There is thus a need to assess the effectiveness of these school-business alignments. The issue is not just what type of skills are needed, for the digital and green labour markets but also at what level; and then how to make acquiring these skills accessible.

CEDEFOP (2018) illustrates the regional diversity in the responsiveness of the VET system to the changing technologies. There are experiments with work-based learning, learning factories and multi-stakeholder approaches with benefits that still need to get evaluated. Cedefop and EUROSTAT jointly work on the Skills-OVATE project, offering detailed information on the jobs and skills employers demand based on online job advertisements in European countries, allowing a better assessment of (future) skill demands.

There is also a lot of investment in making skills, education requirements and training programmes comparable across European countries and linked to professional standards. With Europass, Europe is looking for verifiable credentials related to a relevant competence framework (e.g. the European Qualifications Framework or EQF), and a new skills language is needed (i.e. a common skills classification). The issue is to what extent are claims in any CV verifiable. Technology and standards (e.g., eIDAS[14], eSEAL[15]) are currently used to realise trust in qualifications and claims being made.

Several countries have implemented reforms to incentivise adult learning participation. Again, however, the issue is their effectiveness. According to the OECD (2020a), in the past decades, adult participation rates have risen in only a few countries, for example, Italy and the Netherlands. The low quality of training courses, barriers within companies to encouraging learning, common labour market outcomes from training; poor alignment of training with individual and labour market needs and low inclusivity efforts are potential reasons for the general lack of adult participation in training.

**Bridges 5.0** examines how Industry 5.0 can motivate managers, employees, job seekers and students to participate in further training. The COVID-19 pandemic and the acceleration of the greening of the industry have led to unprecedented imbalances in the labour market, which raises the question of how mobility between sectors can be regulated and what instruments are available to do so (Bredemeier et al., 2022). The EU Competence Framework for Green Skills, for example, was explicitly developed for this purpose. Again, how effective these instruments are needs to be assessed.

To improve the functioning of labour markets and how it is geared towards companies' needs, the underlying institutional relationships must be understood. How do different institutional contexts interact with the chosen measures to support adult participation in further training? The different welfare systems support the working population and job seekers very differently.

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[14] EU regulation on electronic identification and trust services

[15] Electronic Seal

# 5. Summary.

This research note provides a theoretical and conceptual framework to develop solutions for workforce skills in Industry 5.0. It formulated the following observations:

- Industry 5.0 offers a twist to Industry 4.0. It builds on Industry 4.0 and tries to improve its potential. At the same time, Industry 5.0 brings a new perspective on technology development and organisational behaviour in the industry. Companies need to focus on human-centricity, sustainability and resilience. This means that societal values are central to Industry 5.0. Industry 5.0 is firmly embedded in EU policy and needs to find a place at the national level.
- Industry 5.0 is a complex concept with many dimensions, which makes it difficult to precisely define. The scope of this research note is limited to workforce skills. Workforce skills themselves are influenced by changed organisational practices. We offer a redefinition of research, starting by identifying these practices and then seeing what kind of skills are required to function within such new practices. In this context, it is clear that Industry 5.0 has multiple goals, applies to various ecosystem levels in the industrial ecosystem and is directed at different target groups. The research within **Bridges 5.0** will need to take account of this.
- By first studying the dimensions independent from each other and second studying the interactions between these dimensions, it is possible to translate Industry 5.0 into practical actions to support the functioning of companies and the development of the necessary workforce skills. The focus is on requirements for companies and their policy and strategy and what human-centricity, sustainability, and resilience mean for them. Subsequently, this demands a translation into needed workforce skills. The report provides guidelines for this exercise at a general level
- The interaction between Industry 5.0 goals and the target groups amongst the current and future, company policies and other societal actors. This research note has provided a first overview of what these requirements are (see Table 1).
- The interaction between ecosystem levels and the target groups provides the requirements needed for Industry 5.0 workforce skills. These skilling requirements will be further tested over the course of the **Bridges 5.0** project. Especially in the Learning Factory and Teaching Factory environments the implementation of change and technology intervention are subject to this testing.

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# Annexe 1 – Glossary – list of relevant terms.

| Word/term | Working definition | Source |
|---|---|---|
| | | |
| **Artificial Intelligence** | Ability of a machine to use algorithms to analyse their environment, learn from data and use what has been learnt to take actions and make decisions – with some degree of autonomy – to achieve specific goals. | www.cedefop.europa.eu/en/tools/vet-glossary/glossary |
| **Augmented, Mixed, Virtual, and Extended Reality** | Augmented reality (AR) is the integration of digital information with the user's environment in real time, often by combining the camera image of a mobile device with a layer of digital information.<br>Mixed reality is very similar to AR, and the distinction depends on the source. Mixed reality is generally seen as more advanced than AR, e.g. it might be that information is presented in 3D via a head-mounted device such as the MS HoloLens. In AR and MR, the user is able to see the real world directly, instead of via a video image.<br>Virtual reality (VR) creates a totally artificial environment, users are fully immersed and can only see the environment around them if it is recorded via cameras and presented on the VR headset's display.<br>Extended reality (XR) is a catch-all to refer to augmented reality (AR), virtual reality (VR), and mixed reality (MR) | Combination of:<br>What is Augmented Reality (AR)? (techtarget.com)<br>Augmented reality – Wikipedia<br>(Krause et al., 2022) |
| **Automation of work** | Use of technologies, such as advanced robotics and artificial Intelligence to produce and distribute goods and services with minimal human intervention. | www.cedefop.europa.eu/en/tools/vet-glossary/glossary?letter=A#glossary-149957 |
| **Centres of Vocational Excellence (regional CoVEs)** | Centres of Vocational Excellence (CoVEs) are formed by 37 VET centres integrated in networks of partners that develop local "skills ecosystems" to provide high quality vocational skills to young people and adults, and contribute to regional development, innovation, industrial clusters, smart specialisation strategies and social inclusion.<br>Those multifunctional VET centres stimulate local business development and innovation, by working closely with companies (in particular SMEs) on applied research projects, creating knowledge and innovation hubs, as well as supporting entrepreneurial initiatives of their learners. | ec.europa.eu/social/main.jsp ?catId=1501 |
| **Centres of Vocational Excellence (Platforms of CoVEs)** | The Platforms for Centres of Vocational Excellence initiative introduces a European dimension to vocational excellence by supporting the development of Centres of Vocational Excellence, operating at two levels: a) National: Establishing Centres of Vocational Excellence that bring together a wide range of partners contributing to create skills ecosystems responding to local needs. B) International: Through international collaborative networks bringing together Centres of Vocational Excellence that share a common interest in developing skills ecosystems | ec.europa.eu/social/main.jsp ?catId=1501 |
| **Circular economy** | The circular economy is a model of production and consumption, which involves sharing, leasing, reusing, repairing, refurbishing and recycling existing materials and products as long as possible. In this way, the life cycle of products is extended. | www.europarl.europa.eu/news/en/headlines/economy/20151201STO05603/circular-economy-definition-importance-and-benefits |
| **Collaborative robot (cobot)** | A collaborative robot, also known as a cobot, is an industrial robot that can safely operate alongside humans in a shared workspace and that allows direct human robot interaction. | From: Wikipedia and www.techtarget.com/ |
| **Cognitive technologies** | Products of the field of artificial intelligence which are able to perform tasks that only humans used to be able to do. Examples of cognitive technologies include computer vision, machine learning, natural, language processing, speech recognition and robotics. | International Labour Organization (2021) |
| **Competence / competency** | Demonstrated ability to use knowledge, know-how, experience, and – job-related, personal, social or methodological – skills, in work or study situations and in professional and personal development. | Glossary \| CEDEFOP (europa.eu) |

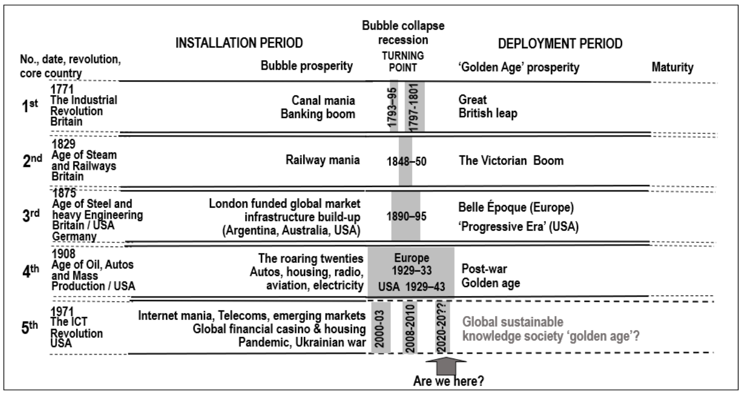
| Word/term | Working definition | Source |
|---|---|---|
| **Core work skills** | A set of nontechnical skills, such as soft, social and emotion cognitive and metacognitive skills, basic skills, including literacy and numeracy, digital literacy and numeracy, and basic environmental awareness, transferable across occupations and jobs. | International Labour Organization (2021) |
| **Cyber-physical systems (CPS)** | Computer-based algorithms that work with physical processes in which embedded computers and networks monitor and control the physical processes of machines and artificial intelligence (AI) in a feedback loop whereby one informs the other | International Labour Organization (2021) |
| **Digitalisation** | Enabling or improving processes by leveraging digital technologies and digitised data | www.arcweb.com/blog/what-digitization-digitalization-digital-transformation |
| | Digitalisation is the use of digital technologies to change a business model and provide new revenue and value-producing opportunities; it is the process of moving to a digital business. | www.gartner.com/en/information-technology/glossary/digitalization |
| **Digitisation** | The process of changing from analogue to digital form, also known as digital enablement | www.gartner.com/en/information-technology/glossary/digitization |
| **Digital skills** | Ability to make confident, critical and responsible use of, and engage with, digital technologies for learning, at work, and for participation in society. It includes information and data literacy, communication and collaboration, media literacy, digital content creation (including programming), safety (including digital well-being and competences related to cybersecurity), intellectual property related questions, problem solving and critical thinking. | Glossary \| CEDEFOP (europa.eu) |
| **Digital twin** | A digital twin is a digital representation of a real-world entity or system. The implementation of a digital twin is an encapsulated software object or model that mirrors a unique physical object, process, organisation, person or other abstraction. Data from multiple digital twins can be aggregated for a composite view across a number of real-world entities, such as a power plant or a city, and their related processes. | www.gartner.com/en/information-technology/glossary/digital-twin |
| **Ecosystem (nature)** | An ecosystem (or ecological system) consists of all the organisms and the physical environment with which they interact. | Ecosystem – Wikipedia |
| **Ecosystem (business)** | A business ecosystem is the network of organisations—including suppliers, distributors, customers, competitors, government agencies, and so on—involved in the delivery of a specific product or service through both competition and cooperation. | www.investopedia.com/terms/ |
| **Ergonomics** | See in this glossary HFE – human factors and ergonomics | iea.cc/about/what-is-ergonomics/ |
| **Employment** | Any remunerated activity undertaken by a person (employed or self-employed) to produce goods or services. | Glossary \| CEDEFOP (europa.eu) |
| **Employment quality** | See Job quality | |
| **Empowerment** | The process of gaining freedom and power to do what you want or to control what happens to you | EMPOWERMENT \| English meaning – Cambridge Dictionary |
| **Entrepreneurship** | Entrepreneurship is the creation or extraction of economic value. With this definition, entrepreneurship is viewed as change, generally entailing risk beyond what is normally encountered in starting a business, which may include other values than simply economic ones. | Wikipedia |
| **Extended reality (XR)** | See Augmented Reality | |
| **Green jobs** | 1. Jobs in businesses that produce goods or provide services that benefit the environment or conserve natural resources.<br>2. Jobs in which workers' duties involve making their establishment's production processes more environmentally friendly or use fewer natural resources. | https://www.bls.gov/green/home.htm#definition |
| **Green skills** | Green skills are the knowledge, abilities, values and attitudes needed to live in, develop and support a sustainable and resource-efficient society. | What are green skills? \| UNIDO |
| **HFE – human factors and ergonomics** | The scientific discipline concerned with the understanding of interactions among humans and other elements of a system, and the profession that applies theory, principles, data, and methods to design in order to optimise human well-being and overall system performance (IEA definition) | iea.cc/about/what-is-ergonomics/ |

| Word/term | Working definition | Source |
|---|---|---|
| **Human Centred** | Adjective, marked by humanistic values and devotion to human welfare<br>synonyms: human-centred, humanist, humanistic, humanitarian.<br>Generally considered in combination with design (approach). See Human centred design | Human-centred Definition, Meaning & Synonyms \| Vocabulary.com |
| **Human centred design** | Human-centred design is an approach to interactive systems development that aims to make systems usable and useful by focusing on the users, their needs and requirements, and by applying human factors/ergonomics, and usability knowledge and techniques. This approach enhances effectiveness and efficiency, improves human well-being, user satisfaction, accessibility and sustainability; and counteracts possible adverse effects of use on human health, safety and performance | ISO 9241-210:2019(E), from<br>Human-centred design - Wikipedia |
| **Human centred organisations** | The human-centred organisation is one that exists to fulfil a purpose for its users, customers, and community, and orients all of its innovation and operations activities around those people.<br>A human-centred organisation:<br>• focuses on creating better human experiences<br>• builds resilience and de-risks innovation through continuous iteration and learning<br>• cares as much about the experience of its diverse, empowered teams as it does about its customers<br>• intentionally, actively embeds these principles into the fabric of the organisation | Human-centred organisations: why and how to build them (ibm.com) |
| **Human-centric** | From Human-centric approach: taking core human needs and interests into account | |
| **Human-centric approach** | Human-centric approach in industry puts core human needs and interests at the heart of the production process | EU policy brief – Industry 5.0 |
| **Human-centric workplace** | A human-centric workplace is one that revolves around its people and considers their specific needs.<br>Using human-centred design, we can apply the theory to crafting our workplaces.<br>Strategies to humanise your workplace:<br>• Offer flexibility<br>• Recognise achievements<br>• Focus on employee wellness<br>• Create team goals<br>• Office layout matters<br>• Provide learning and development opportunities | 6 strategies to create a human-centric workplace (jostle.me) |
| **Industrial revolutions (first to third)**<br><br>**(see also 'technological revolutions')** | Industry 1–0 - initial attempts toward mechanisation supported by the steam engines of water power,<br>Industry 2–0 - the period of electricity guided, assembly line supported mass production,<br>Industry 3–0 - the stage of computer technologies leading effective automated systems, | Tinmaz (2020) |

| Word/term | Working definition | Source |
|---|---|---|
| **Industry 4.0** | Industry 4.0—also called the Fourth Industrial Revolution or 4IR—is the next phase in the digitisation of the manufacturing sector, driven by disruptive trends including the rise of data and connectivity, analytics, human-machine interaction, and improvements in robotics.<br>Industry 4.0 brings these inventions (digital technologies) beyond the previous realm of possibility with four foundational types of disruptive technologies (examples below) that can be applied all along the value chain:<br>• connectivity, data, and computational power: cloud technology, the Internet, blockchain, sensors<br>• analytics and intelligence: advanced analytics, machine learning, artificial intelligence<br>• human–machine interaction: virtual reality (VR) and augmented reality (AR), robotics and automation, autonomous guided vehicles<br>• advanced engineering: additive manufacturing (such as, 3-D printing), renewable energy, nanoparticles<br>Technology, however, is only half of the Industry 4.0 equation. To thrive in the Fourth Industrial Revolution, companies must ensure that their workers are properly equipped through upskilling and reskilling and then hire new people when necessary | What is industry 4.0 and the Fourth Industrial Revolution? \| McKinsey |
| **Industry 5.0** | A coherent vision for the future of European industry. This vision recognises the power of industry to achieve societal goals beyond jobs and growth, to become a resilient provider of prosperity, by making production respect the boundaries of our planet and placing the wellbeing of the industry worker at the centre of the production process. | EU Policy brief – Industry 5.0 |
| **Innovation** | Innovation is the practical implementation of ideas that result in the introduction of new goods or services or improvement in offering goods or services. ISO TC 279 in the standard ISO 56000:2020 defines innovation “s "a new or changed entity realizing or redistributing value". | Innovation - Wikipedia |
| **Internet of Things (IoT)** | system of interrelated computing devices, mechanical and digital machines, objects, animals or people that are provided with unique identifiers and the ability to transfer data over a network without requiring human-to-human or human-to-computer interaction. | International Labour Organization (2021) |
| **Job** | A set of tasks and duties performed, or meant to be performed, by one person, including for an employer or in self-employment | International Labour Organization (2021) |
| **Job quality** | The quality of a job. OECD consider three objective and measurable dimensions:<br>• Earnings quality<br>• Labour market security<br>• Quality of the working environment | Job quality - OECD |
| **Learning Factory** | A learning factory is a learning environment where processes and technologies are based on a real industrial site which allows a direct approach to product creation process (product development, manufacturing, quality-management, logistics).<br>Learning factories are based on a didactical concept emphasising experimental and problem-based learning. The continuous improvement philosophy is facilitated by own actions and interactive involvement of the participants.” | International association of Learning Factories (2021)<br>ialf-online.net/ |
| **Life long learning** | Lifelong learning is the ongoing, voluntary, and self-motivated pursuit of knowledge for either personal or professional reasons. It is important for an individual's competitiveness and employability, but also enhances social inclusion, active citizenship, and personal development. | Lifelong learning - Wikipedia |
| **Mixed Reality (MR)** | See Augmented Reality | |
| **Occupation** | Set of jobs whose main tasks and duties are characterised by a high degree of similarity (based on ILO, 2008) | Glossary \| CEDEFOP (europa.eu) |
| **Qualification** | Formal expression of the vocational or professional abilities of a worker which are recognized at international, national or sectoral levels and which takes the form of an official record (certificate or diploma) of achievement, attesting to successful completion of education or training, or satisfactory performance in a test or examination | International Labour Organization (2021) |

| Word/term | Working definition | Source |
|---|---|---|
| **Region** | A part of Europe, who's division is based on geographical, cultural of historical factors. Since there is no universal agreement on Europe's regional composition, the placement of individual countries may vary based on criteria being used. | Regions of Europe - Wikipedia |
| **Resilience** | A higher degree of robustness in industrial production, arming it better against disruptions and making sure it can provide and support critical infrastructure in times of crisis | www.britannica.com/dictionary/resilience |
| **Reskilling** | Training enabling individuals to acquire new skills giving access either to a new occupation or to new professional activities. | Glossary \| CEDEFOP (europa.eu) |
| **Robot** | A robot is a programmable machine capable of carrying out a complex series of actions automatically. A robot can be guided by an external control device, or the control may be embedded within | Robot - Wikipedia |
| **Robotisation** | The introduction of robots to carry out industrial tasks | www.collinsdictionary.com/ |
| **Skill** | Ability to apply knowledge and use know-how to complete tasks and solve problems. Skills can be described as cognitive (involving the use of logical, intuitive and creative thinking) or practical (involving manual dexterity and the use of methods, materials, tools and instruments)<br>Skills are a part of competence | Skills and training \| Eurofound (europa.eu) |
| **Skills ecosystem** | Community (businesses, industry/sector, education and training providers, NGOs, local or regional stakeholders, etc.) in which individuals and organisations connect and interact to address skill needs and develop, use and transmit, in an autonomous way, knowledge, abilities and competencies. | www.cedefop.europa.eu/en/tools/vet-glossary/glossary?letter=S#glossary-150326 |
| **Skills gap** | Situation in which the skills level of as employee or group of employees is lower than that required to perform the job adequately, or the type of skill does not match the job requirements | International Labour Organization (2021) |
| **Skills governance** | Process of involving stakeholders from the public, private and third sector, from different economic sectors and geographic units, in generating, disseminating and using skills intelligence to steer policies aimed at balancing skill supply and demand, and to establish a basis for stimulating economic development via targeted investments in skills development. | Glossary \| CEDEFOP (europa.eu) |
| **Skills intelligence** | Process of identifying, collecting, analysing, synthesising and presenting quantitative or qualitative information on skills and labour market to:<br>• identify key trends and demands in the labour market;<br>• assess, anticipate and forecast skill needs;<br>• address skill gaps and mismatches;<br>• adapt provision of education and training accordingly;<br>• provide relevant educational and career guidance and counselling. | Glossary \| CEDEFOP (europa.eu) |
| **Skills management system / competence management system** | A system to manage skills and competence development and to ensure that the individual and organisation training plans are linked to business goals. | Homer (2001) |
| **Skills mismatch** | Term referring to different types of skills gaps and imbalances such as over-education, undereducation, overqualification, underqualification, over-skilling, skills shortages and surpluses, and skills obsolescence.<br>Skills mismatch can be both qualitative and quantitative, referring both to situations where a person does not meet the job requirements and where there is a shortage or surplus of persons with a specific skill. Skills mismatch can be identified at the individual, employer, sector or economy level. | International Labour Organization (2021) |
| **Skills shortage** | Situation in which certain skills are in short supply, for example where the number of job seekers with certain skills is insufficient to fill all available job vacancies | International Labour Organization (2021) |
| **Small firm** | See SME | |
| **Smart specialisation** | A place-based approach characterised by the identification of strategic areas for intervention based both on the analysis of the strengths and potential of the economy and on an Entrepreneurial Discovery Process (EDP) with wide stakeholder involvement. It is outward-looking and embraces a broad view of innovation including but certainly not limited to technology-driven approaches, supported by effective monitoring mechanisms | Website European Commission |

| Word/term | Working definition | Source |
|---|---|---|
| **SME / micro, small, medium firm** | Small and medium-sized enterprises (SMEs) are defined in the EU recommendation 2003/361EN.<br>The main factors determining whether an enterprise is an SME are:<br>• staff headcount (micro <10, small <50, medium <250 employees), either<br>• turnover (micro <2M, small <10M, medium <50M Euro), or<br>• balance sheet total (micro <2M, small <10M, medium <43M Euro) | SME definition (europa.eu) |
| **Socio-centric** | The tendency to put the needs, concerns, and perspective of the social unit or group before one's individual, egocentric concerns. In that way it is analogous to human-centric, namely putting core *societal* needs and interests at the heart of the production process | APA Dictionary of Psychology |
| **Social Innovation** | Social innovations are new ideas that meet social needs, create social relationships and form new collaborations. These innovations can be products, services or models addressing unmet needs more effectively. | single-market-economy.ec.europa.eu/industry/strategy/innovation/social_en. |
| **Socio-technology** | The study and explanation of how technical instrumentation and division of labour interdependence and in relation to data environmental conditions, the system behaviour, the determine system capacity and system functions, as well as the application of this knowledge in the designing and redesigning production systems. | Translated from De Sitter's definition (1974), in: Van Eijnatten (1992) |
| **Supply chain** | A supply chain is a complex logistics system that consists of facilities that convert raw materials into finished products which are later distributed to end consumers or end customers. Meanwhile, supply chain management deals with the flow of goods within the supply chain in the most efficient manner. | Supply chain - Wikipedia |
| **Sustainability** | Sustainability is a societal goal that relates to the ability of people to safely co-exist on Earth over a long time. […] Sustainability is commonly described as having three dimensions (or pillars): environmental, economic, and social. Many publications state that the environmental dimension is the most important. For this reason, in everyday use, sustainability is often focused on countering major environmental problems, such as climate change, loss of biodiversity, loss of ecosystem services, land degradation, and air and water pollution. The concept of sustainability can be used to guide decisions at the global, national, and individual levels (e.g. sustainable living). | Sustainabiliy - Wikipedia |
| **Teaching Factory** | The Teaching Factory is a concept that aims to align manufacturing teaching and training to the needs of modern industrial practice. It aims The Teaching Factory paradigm comprises the relevant educational approach and the necessary ICT configuration for the facilitation of interaction between industry and academia. The Teaching Factory aims at a two-way knowledge communication between academia and industry. | Teaching Factory Competence Center – (teachingfactory-cc.eu)<br>and<br>Chryssolouris et al., (2016) |
| **Technological innovation** | Technological innovation is the process where an organisation (or a group of people working outside a structured organisation) embarks in a journey where the importance of technology as a source of innovation has been identified as a critical success factor for increased market competitiveness | en.wikipedia.org/wiki/Technological_innovation |

| Word/term | Working definition | Source |
|---|---|---|
| **Technological Revolution** | Technological Revolution is a period in which one or more technologies is replaced by another novel technology in a short amount of time.<br><br>Five technological revolutions (Perez, 2023):<br> | en.wikipedia.org/wiki/Technological_revolution<br><br>Perez (2023) |
| **Upskilling** | Short-term targeted training typically provided following initial education or training, and aimed at supplementing, improving or updating knowledge, skills and competences. | www.cedefop.europa.eu/en/tools/vet-glossary/glossary?letter=U |
| **Virtual Reality** | See Augmented Reality | |
| **Work** | Work or labour is the intentional activity people perform to support the needs and wants of themselves, others, or a wider community. In the context of economics, work can be viewed as the human activity that contributes (along with other factors of production) towards the goods and services within an economy. | Work (human activity) - Wikipedia |
| **Work environment** | The work environment is the environment, both physical and human, in which a certain activity or work takes place | http://www.definebusinessterms.com/working-environment |
| **Workplace** | Workplace is a location where someone works, for their employer or themselves, a place of employment. | en.wikipedia.org/wiki/Workplace |
| **Workplace innovation** | Workplace Innovation' defines evidence-based organisational practices that enable employees at every level to use and develop their skills, knowledge, experience and creativity to the fullest possible extent, simultaneously enhancing business performance, engagement and well-being. | Totterdill et al (2002) |
| **Work organisation** | Work organisation refers to how work is planned, organised and managed within companies and to choices on a range of aspects such as work processes, job design, responsibilities, task allocation, work scheduling, work pace, rules and procedures, and decision-making processes. | www.eurofound.europa.eu/topic/work-organisation |
| **Work quality** | The standard of work that an employee or team delivers consistently | Indeed.com |

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# Annexe 2 – The role of social innovation.

- Industry 5.0 in perspective of social innovation

A widely non-normative and practice-theoretically based **definition** of **social innovation,** developed by Howaldt and Schwarz, is *„a new combination and/or a new configuration of social practices in certain areas of action or social contexts prompted by certain actors or constellations of actors in an intentional targeted manner with the goal of better satisfying or answering needs and problems than is possible on the basis of established practices. An innovation is, therefore, social to the extent that it, conveyed by the market or 'non/without profit', is socially accepted and diffused widely throughout society or in certain societal subareas, transformed depending on circumstances and ultimately institutionalized as new social practice or made routine"* (Howaldt & Schwarz 2010, p. 54).

The preoccupation with the problem of sustainable development drew attention early on to the special importance of social innovations for shaping socio-ecological transformation processes (e.g. energy transition, mobility transition, adaptation to climate change, digitalisation) and their governance. Insofar the conception of **social innovation as part of a comprehensive innovation approach** can help to bring the ambitions from industry5.0 into practice: to make better use of digitalisation for solving societal challenges like sustainability transformations. At the same time social innovation provides profound know-how in designing human-centric, resilient and sustainable workplaces and organisations (Howaldt et al. 2016).

- Social Innovation in context of Industry 4.0 and Industry 5.0

The Federal Ministry of Education and Research (BMBF, 2014; 2016) in Germany summarizes in a concise manner the **potential of social innovation for the future of work** when it states: *"The challenge lies not only in the new technologies themselves, but above all in the reconfiguration of social action and a new interrelationship between technology and society. What the new should look like is open. In enterprises, this requires participatory and trust-based design processes with the participation of different employee groups. Beyond the companies, this means the entry of customers and civil society along existing and newly forming value chains. Therefore, the reorganisation of internal company activities and the interrelationship between technology and social issues. Within the company, participatory and trust-based models of interaction for the various players must be facilitated; externally, the institutional context (economic, political, social, cultural) must be taken into account. Producing sustainable innovations under knowledge-intensive conditions represents a major social challenge. With Economy 4.0, completely new worlds of work and learning are emerging that require considerable research in the fields of technology, human resources, organisation and skills acquisition. At the organisational level, more attention is needed to social innovations and new insights into how social innovations emerge and can be implemented in companies. A knowledge-based economy as a prerequisite for maintaining and expanding the competitiveness of the German and European economy is inconceivable without the development of promotion of innovation, management concepts and organisational structure. Social innovation starts at the workplace; it requires modern work environments that enable greater self-organisation and allow more freedom for the individual design of the workplace and the work process. [...] For the full development of technological potentials, a comprehensive understanding of innovation that sustainably anchors social and technological innovations in the companies in a long term and implemented in a systematic way"* (BMBF, 2016, p. 20f.).

This understanding led to a critical accompaniment of the implementation of Industrie4.0-technologies. Critical labour research, labour science, trade unions and initiatives of the Ministry of Labour and Social Affairs have critically accompanied the development of Industry 4.0 and tried from the beginning to counteract technological shortcuts and to develop human-centred design perspectives (Kopp, 2016). Central points of criticism according to Industry 4.0 are similar like EU criticism. This means in many aspects **Industry 5.0 can be built upon concepts and experiences that have already been developed as part of the critical analysis and accompaniment of Industry 4.0** through action strategies and design principles from social innovation, workplace innovation and socio-technical approaches. They have found expression in many application-oriented research projects in recent years strengthened by the allocation of significant resources in context of research programs at the regional, national and European levels (e.g. ERANET-MANUNET, Horizon 2020).

Schröder (in Howaldt & Kaletka, 2023) sees social innovation as a driver for a **triple transition** (digital, green and social) from Industry 4.0 to Industry 5.0. For this view it is needed to combine social and technological innovation processes. Technology should be seen as support for humans to create better workplaces and to stronger address societal needs. This makes it necessary to overcome techno-centric approaches with orientation only on efficiency and growth targets. As the authors show, social innovation extends beyond enterprise boundaries and aims to collaborate with numerous other stakeholders to develop sustainable supply chains, to create a circular economy) and –in sense of open innovation and co-creation– to generate information about needs and solution ideas from supplier, user and other stakeholder like the civil society (ibid.) This leads to holistic sociotechnical systems (Kohlgrüber, Schröder, Yusta & Ayarza, 2019) or in other terms to extended **social innovation ecosystems** (Balloni, Azevedo & Silveira, 2012).

- Perspectives for social innovation in context of Industry 5.0

Industry 5.0 aims, among other things, to activate and involve many different stakeholders in corporate governance: "Success depends on the widest possible engagement and action of all stakeholders (Breque, De Nul & Petridis, 2021, p. 4). Against this background enterprises have begun *“to create relationships with civil society and social economy organisations and is becoming more involved in social initiatives. Concepts such as Environmental, Social and Governance (ESG) standards, Corporate Social Responsibility (CSR), shared value (Porter and Kramer, 2011[27]), inclusive business and the global social purpose or B Corporation movements are increasingly evident in private sector practices. (…) Increasingly, private sector actors realise that without collaboration with other actors they are unable to solve complex societal issues on their own and are eager to be part of the change.”* (OECD 2021: 16)

Many social innovation initiatives are linked to efficiency and (green) growth strategies. The EU proposals for Industry 5.0 are also within this framework. Social innovation is based on comprising aspects like human dignity, solidarity, ecological sustainability, social justice as well as democratic co-determination and transparency related to different stakeholders such as suppliers, financial backers, employees including owners, customers, etc. In addition, there are negative criteria, which are weighted differently as malus and may affect the balance accordingly.

- Perspectives for social innovation in context of **Bridges 5.0**

Social innovation can take place at different interrelated levels and with specific (institutional) actors and stakeholders. In terms of Industry 4.0+5.0, the spectrum ranges from individual workplaces, teams, departments, plants, value and supply chains to regional networks and social transformation processes at local or regional level. The social innovation perspective in **Bridges 5.0** contains two approaches: a human-centric and socio-centric approach. The **human-centric approach** puts core to human needs and interests at the heart of the production process rather than taking emergent technology as the starting point and examining its potential for increasing efficiency. This approach is strongly connected with **workplace innovation** focusing on new educational and training efforts at the **company level**. Using a human-centric and ethical approach it allows expanding the assessment of skills needed at work.

But the digitalisation of industry is so fast that investments in training settings in schooling systems quickly become obsolete. The required high speed of adaptation of skills development cannot be achieved at the company level alone, but requires embedding in a broader, i.e. regional, framework of action involving other actors. New agreements and practices of cooperation between the stakeholders in the educational field are necessary.

The **socio-centric approach** focusses on the stimulation of new social practices in companies, more social ownership and market uptake of solutions developed. It is broader than the human-centric approach and recognises that technologies are part of systems that are organised to further societal and ecological values and targets (e.g. social-ecological transformations). This could be linked to a large number of processes (e.g. personnel and organisational development, digitisation, product development, business models), policy areas (e.g. innovation policy, research policy, regional development, social policy, transport policy) and necessary infrastructure (e.g. education and training systems, transport routes). The term of **social innovation ecosystem** (OECD 2021) helps to label this complex field of dynamic interconnection and interaction focused to materialize a certain value proposition between multiple actors (Moore 1993).

Wherever **Bridges 5.0** ' actions extend beyond the company level and stakeholders from beyond the company level or from other sectors of society have to undergo co-evolutionary development and learning processes, it is a matter of managing social innovation ecosystems. Socio-centric approaches, respectively social innovation ecosystems in context of **Bridges 5.0** are relevant for the teaching and learning factory, for cooperation with actors from education and training system but also for developing sustainable and ecological products and processes aligned with societal needs. Furthermore the development of a platform is not only a question of technology and content but also a multi-stakeholder process. In other words a platform is to be embedded in a social ecosystem.

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# Annexe 3 – Designing Industry 5.0 procedures.

- How to assess the state of Industry 5.0 and how to design Industry 5.0 with the desired impacts

In **Bridges 5.0**, among others, 'Teaching and Learning factory-based interventions' (WP5 for companies and WP6 for associations) are to take place. Through collaborating with companies and stakeholders that will revisit technologies and digitalisation, and are planning to study the needed workforce skills, redesigning the situation in accordance with I5.0 conditions. Additionally, the integration of change management will have to be regarded in many cases. However, to be able to handle cases where not all potential requirements can be met, we are proposing a conditional approach.
For this purpose we are proposing a ***conditional*** design science approach which is a combination of 'design science research' and sociotechnical systems design or sociotechnics. A conditional approach means that users focus on creating the conditions that meet the desired impacts. This can in principle be applied to every level, but the focus is on company level including the personal / job level.

- Design Science

Design science is a research paradigm focusing on the development and validation of prescriptive knowledge (Van Aken, 2005; Van Aken et al., 2007; Van Aken & Romme, 2012). Simon (1988) distinguished the natural sciences, concerned with explaining how things are, from design sciences which are concerned with how things ought to be, that is, with devising artifacts (such as specific business systems) to attain goals. Design science research focuses on the development and performance of (designed) artifacts with the explicit intention of improving the functional performance of the artifact. Design science research is typically applied to categories of artifacts including algorithms, human/computer interfaces, design methodologies (including process models) and languages. Its application is most notable in the Engineering and Computer Science disciplines, though is not restricted to these and can be found in many disciplines and fields. Design science research, or constructive research, in contrast to explanatory science research, has academic research objectives generally of a more pragmatic nature.
The approach of Van Aken et al., (2007) is a methodology for problem-solving in organisations or, in other words, for business problem-solving. Business problem-solving (BPS) is very different from business research. The business research methodology is similar to the general social science research methodology. That is a methodology for analysing, describing and explaining that what is, focusing on the development of (usually general) knowledge. In business problem-solving, on the other hand, the focus is on designing that what can be, or that what should be in order to improve the performance of a specific business system on one or more criteria. In order to be able to design a business system, or to redesign an existing one, one must analyse the present one and the possible causes of its less than satisfactory performance. For that, many classic (and non-classic for that matter) methods of social science research can help. But problem analysis is only the first part of business problem-solving, and analysis should be in the service of the design of solutions (and the necessary change plans). Therefore the methodology given here is design-focused: problem-solving projects aim at the design of a sound solution and at the realisation of performance improvement through planned change, and not merely at sophisticated analyses (science for the sake of science). The methodology of this approach is also theory-based. In practice, problem-solving in organisations is often undertaken in a craftsman-like fashion, based on business experience and informed common sense. The methodology is theory-based: based on state-of-the-art literature, on the type of business systems and type of problems in

question, and on the methods to be used in solving business problems (including common sense and experience).

Van Aken's approach (2007) builds on the traditions of rational problem-solving. The type of problems best suited to this approach should have a significant technical economic content. At the same time they recognise that organisations are social systems, that the realisation of improvements in business system performance entails organisational change, and that effective organisational change does not only need technical-economic interventions (like the presentation of a promising solution for a problem), but political and cultural ones as well (i.e. a sociotechnical approach). Therefore the focus is not only on technical solution design, but also on the design of the change process needed to realise the performance improvement, and on the development of organisational support for a solution and change plan.

A Business Problem-Solving (BPS) project (Van Aken et al., 2007) typically consists of an analysis and design part, an organisational change part, and a learning part, during which the organisation learns to realise improved performance on the basis of the designed solution. The methodology focuses on the design of the solution for the business problem, the design of the change process needed to realise that solution in new or adapted roles and procedures, and the analyses needed to make those designs. Hence the term 'design-focused'.

From the perspective of the client organisation a full BPS project consists of three parts (Van Aken et al., 2007):

- a design part, in which a redesign of the business system or organisational unit is made based on the problem definition, analysis and diagnosis; a change plan for introducing the redesign; and the development of an organisational support structure for the solution and change plan;
- a change part, in which the redesign is realised through changes in organisational roles and routines, plus the possible implementation of new tools or information systems;
- a learning part, in which the client organisation learns to operate within the new system and with the new instruments and learns to realise the intended performance improvement. An organisation needs time to recover after a significant change. People have to relearn how to work effectively and efficiently within their new situation, which takes time, effort and management attention.

A sound BPS project has to satisfy the following quality criteria (Van Aken et al., 2007):

- performance-focused; the actual performance improvement is the primary objective of the project
- design-oriented; the activities during the project are controlled through a sound project plan;
- theory-based; using valid, state-of-the-art knowledge for the analysis and design activities;
- justified; one justifies the proposed solution vis-a-vis the client organisation. This is done firstly by describing the process through which the solution has been designed; and secondly by an explanation of why the designed solution will solve the problem;
- client-centred: one deals respectfully with the client system as a whole (the principal, the problem owner, people working in the redesigned business system, and other stakeholders).

In a BPS the CIMO-logic (Denyer et al., 2008) is followed as a guideline of causality, i.e. by asking through which generative mechanism(s) the intervention produces the outcome in the given context, which is as follows: For this problem-in-**C**ontext it is useful to use this **I**ntervention, which will produce through these **M**echanisms this **O**utcome. The intervention typically is the implementation of a generic system design. This CIMO logic has the form of design propositions, and is constructed as follows:

- in this class of problematic Contexts,
- use this Intervention type
- to invoke these generative Mechanism(s)
- to deliver these Outcome(s).

A specific example of a design proposition following CIMO-logic might be:
*'If you have a project assignment for a geographically distributed team (class of contexts), use a face-to-face kick-off meeting (intervention type) to create an effective team (intended outcome) through the creation of collective task insight and commitment (generative mechanisms).'*
Design propositions created in this way therefore contain information on what to do, in which situations, to produce what effect and offer some understanding of why this happens (Van Aken et al., 2007).

Table 1.
CIMO-logic—the Components of Design Propositions

| Component | Explanation |
|---|---|
| Context (C) | The surrounding (external and internal environment) factors and the nature of the human actors that influence behavioural change. They include features such as age, experience, competency, organizational politics and power, the nature of the technical system, organizational stability, uncertainty and system interdependencies. Interventions are always embedded in a social system and, as noted by Pawson and Tilley (1997), will be affected by at least four contextual layers: the individual, the interpersonal relationships, institutional setting and the wider infrastructural system. |
| Interventions (I) | The interventions managers have at their disposal to influence behaviour. For example, leadership style, planning and control systems, training, performance management. It is important to note that it is necessary to examine not just the nature of the intervention but also how it is implemented. Furthermore, interventions carry with them hypotheses, which may or may not be shared. For example, 'financial incentives will lead to higher worker motivation'. |
| Mechanisms (M) | The mechanism that in a certain context is triggered by the intervention. For instance, empowerment offers employees the means to contribute to some activity beyond their normal tasks or outside their normal sphere of interest, which then prompts participation and responsibility, offering the potential of long-term benefits to them and/or to their organization. |
| Outcome (O) | The outcome of the intervention in its various aspects, such as performance improvement, cost reduction or low error rates. |

Source: Denyer, Tranfield & Van Aken, 2008, p. 397.

While design science is an approach without no other than methodological normative choices, the sociotechnical design approach is rooted in the jointly optimisation of technical and social systems, with a strong influence from the 'human relations' and 'quality of work' streams. These streams contend that high job quality is beneficial to both organisational and individual performance (objectively) and personal psychosocial well-being (subjectively).

- Sociotechnical design thinking

The essence of sociotechnical systems design thinking (STS-D) is based on two empirically based crucial insights (Govers & Van Amelsvoort, 2023). First, a focus on technology alone led to lower productivity and a decline in the quality of working life. Second, a participatory approach with a simultaneous focus on technology and social aspects led to improvements in both productivity and quality of working life. This led to the general, original principles of STS: organisation as an open system (organisations must learn to deal with the external world of stakeholders), organisational choice (there are alternatives to classical Taylor-based organisations), joint optimisation of social and technical aspects, and participatory design. In STS-D, at least in the Lowlands variant (Govers & Van Amelsvoort, 2023), the division of labour is considered to be key as it offers a common starting point for both digital and organisational design: the division of a core work process into tasks and roles and allocated to people and machines leads to designing execution tasks and related regulation tasks. Therefore the division of labour is a core button to design human-centric work environments. Unpredictable, unstable and turbulent business environments require high quality workers to effectively anticipate and respond and keep production and servicing on the right track, adding value for customers. Bureaucratic organisations with a maximised division of labour create a need for extensive coordination between a multitude of dependencies, that cannot adequately cope with turbulent environments. Such organisations encounter unfavourable business performance and low quality jobs. Human-centricity, resilience and sustainability are far out of sight. The turbulence is largely caused by external factors (markets, technology / digitalisation, labour supply, finance, geo-political disruptions, etc.) for which management and organisations need adequate answers. What turbulent business environments require are not offered by bureaucratic, rigid ways of organising, but by flow-based, alert ways of organising that can act like responsive complex processing entities. Contrary to ‘complex organisation with simple jobs’ (De Sitter et al, 1997), sociotechnical design proposes the opposite: ‘complex jobs in simple organisations’. Complex jobs are based on the minimalisation of the division of labour. While dividing labour, STS makes a distinction between execution and regulation (Govers & Van Amelsvoort, 2023). Regulation is the mix of control of work (coordination, monitoring and reducing interference) and organising work (norm setting, planning, improving, and designing the work). Regulation concerns managing the work, while execution is merely carrying out the tasks and assignments. Job quality, and thus human-centricity, is affected by design choices how to divide the regulatory and executing tasks.

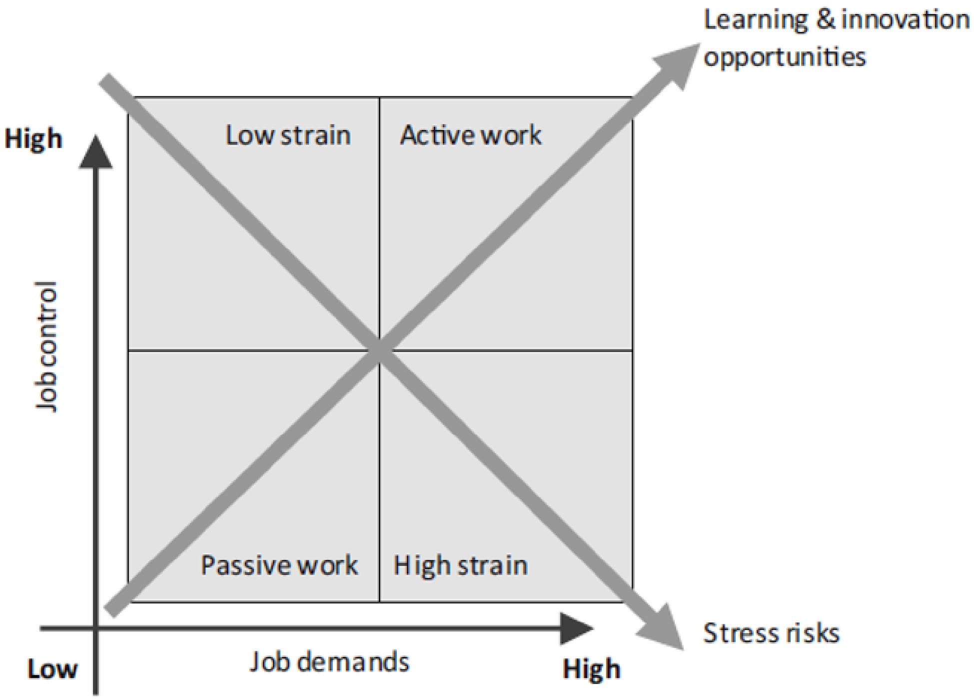


*Figure 3.1 The Job Demand Control model of Karasek*

The division of labour, in terms of allocating high or low levels of autonomy to jobs (job control or regulation), and in setting high or low job demands (the qualitative and qualitative workload), creates four types of work according to Karasek (1979). Only the combination of high job control and high job demands leads to active work with learning and innovation opportunities (see Figure 3.1). These jobs are complex, but skilled workers can deal with the demands because they have the autonomy to regulate all kind of situations in their work. Following the reasoning of the founder of sociotechnical thinking in the Lowlands, De Sitter (1997), Govers and Van Amelsvoort (2023) argue that job control constitutes an important predictor of employee engagement and, as such, an important explanation of employee innovation adoption (Oeij et al, 2022) when introducing digital technologies. In fact, STS-D argues that increased job control encourages workers to learn, allows them to cope more effective with disturbances and therefore prepares them better to respond to challenges arising from task demands. This increased level of job control not only impacts employee engagement, but also benefits the organisation by enabling a better use of human talent, thus enabling the goals of a ‘simple’ (in the sense of a minimised need to govern a multitude of interdependencies) organisation. Therefore, learning and teaching interventions and the implementation and application of digital technology should take the division of labour into account (De Sitter, 1997; Govers & Van Amelsvoort, 2023).

Govers & Van Amelsvoort (2019, 2023) suggest that work can be specified by two dimensions: complexity of work and the elements of work. Complexity can consist of repetitive, deductive, and exploratory tasks. Elements comprise of executive and regulatory work (i.e., controlling and organising task elements). This leads to a 3x3 table with 9 types of tasks. The specific types of complexity and elements are illustrated in Figure 3.2.

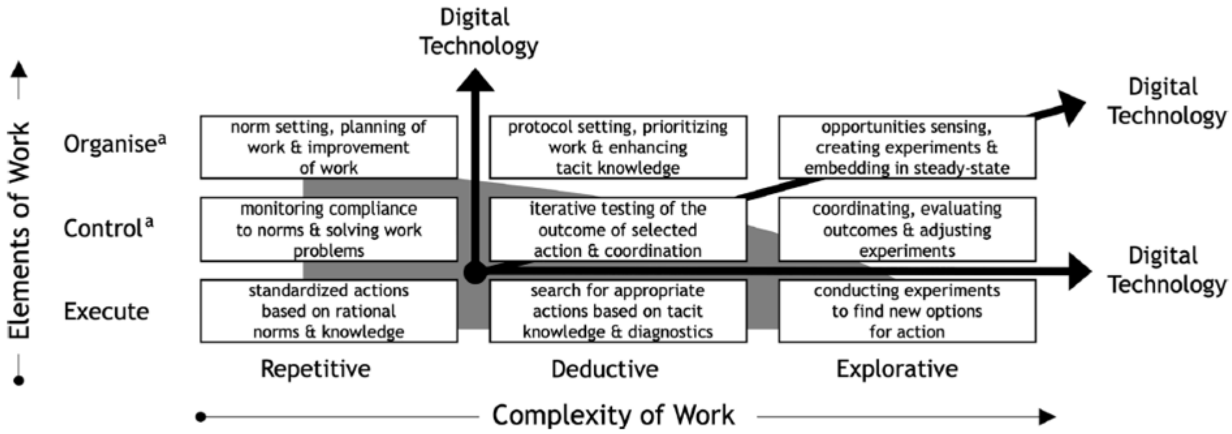


*Figure 3.2 Penetration of digital technology into the nature of work (Source: Govers & Van Amelsvoort, 2023, p. 7.)*

According to Govers & Van Amelsvoort (2023), especially intelligent digital technologies can penetrate into all work elements of repetitive work and into the regulating work elements of deductive and maybe even explorative work. Repetitive work is expected to be more affected by these roles than deductive and explorative work which are more complex of nature. They refer to Malone (2022), who identifies four roles for digital technology to interact with humans which indicate levels of interaction intensity between digital technology and humans:

- <u>Tool:</u> the role where computers perform tasks given to them monitored by humans. For instance, a word processor is a tool to support humans in their work.
- <u>Assistant:</u> the role where computers perform tasks without direct attention of humans. For instance, IBM's Watson technology processes vast amount of medical literature which is used to support a doctor diagnosing a particular medical case.
- <u>Peer:</u> the role where computers perform tasks very much like what humans do. For instance, a computer completely handles an insurance claim received by an app, from receiving the claim till automatically paying the claim within seconds, if the claim is within a set of parameters.
- <u>Manager</u>: the role where computers perform tasks to manage humans. For instance, a workflow system that assigns tasks to people and monitors due dates.

The purpose of applying sociotechnical thinking is to take the desired impacts (of human-centricity, resilience and sustainability) at company level and job level as a starting point. These desired impacts are in fact the **conditions** (functional design criteria) that must be met by the intervention, the implemented innovation. By making a causal analysis in terms of outputs > throughputs > inputs (inversion of the system analysis) one can trace back what happened in the design steps at the company – department – team – job level. Any design 'mistakes' can be identified and improved and adapted.

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# BRIDGES 5.0 PROJECT IDENTITY.

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|---|---|
| **Project name** | BRIDGES 5.0 **B**ridging **R**isks to an **I**nclusive **D**igital and **G**reen future by **E**nhancing workforce **S**kills for industry 5.0 |
| **Coordinator** | **Prof. Dr Steven Dhondt (scientific coordinator).Nederlandse Organisatie Voor Toegepast Natuurwetenschappelijk Onderzoek (TNO), (Netherlands)** |
| **Consortium** | Katholieke Universiteit Leuven<br>Austrian Institute of Technology<br>Panepistimio Patron (Patras University)<br>Conservatoire National des Arts et Métiers, Centre d'Études de l'Emploi et du Travail-Lirsa<br>Departamento de Educacion del Gobierno Vasco<br>The University of Warwick<br>Technische Universität Dortmund<br>Stichting Platform Beta en Techniek<br>Mondragon Goi Eskola Politeknikoa, Jose Maria Arizmendiarrieta S Coop<br>Lietuvos Pramonininku Konfederacija<br>Universita degli Studi di Bari Aldo Moro<br>Universitetet I Agder<br>Workplace Innovation Europe CLG<br>Comau SPA<br>Infineon Technologies Austria AG<br>UAB Kitron<br>Industrie 4.0 Plattform Osterreich<br>Kriziu tyrimo centras (Hybridlab)<br>FH Joanneum Gesellshaft MBH<br>Kauno Technologijos Universitetas |
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