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Measuring Industry 5.0: A KPI-Based Approach to Resilience, Sustainability, and Human Centricity

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Abstract

Industry 5.0 extends industrial transformation beyond technological and efficiency-oriented objectives by emphasizing human centricity, sustainability, and resilience. This study investigates how two industrial companies operating in different sectors address this transition using a common set of key performance indicators (KPIs) developed within the PROSPECTS 5.0 project. The KPI set was previously derived from a systematic review of academic and policy literature and subsequently refined through stakeholder consultation, a Delphi process, and industrial workshops. In the present study, these KPIs are used as a structured analytical framework to examine their relevance, availability, and practical applicability in a logistics company and a manufacturing company. The cross-case comparison shows that several indicators are already monitored through existing management systems and standards, but their applicability and interpretation vary according to sector, company characteristics, data availability, and organizational priorities. The manufacturing company exhibits broader coverage of sustainability and resilience indicators, whereas the logistics company relies on a more selective set of indicators adapted to its operational context. The findings also show that existing indicators can provide a useful starting point for examining Industry 5.0-related practices, although they do not by themselves constitute a standardized composite score or maturity model. The study contributes an exploratory cross-sector analysis of how a common KPI framework can support companies in identifying current practices, context-specific gaps, and priorities related to the transition toward Industry 5.0.

Keywords: Industry 5.0; key performance indicators; human centricity; sustainability; resilience; comparative case study; industrial transformation; management standards

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1. Introduction

The Industry 4.0 paradigm, also known as the Fourth Industrial Revolution, is now firmly established and represents a significant transformation in manufacturing and industry through the integration of advanced technologies. This paradigm focuses on the use of

cyber-physical systems, the Internet of Things (IoT) and cloud computing to create smart factories. Industry 4.0 introduced the concept of Smart Manufacturing, which involves the use of advanced sensors, embedded software and robotics to collect and analyze data, leading to real-time decision-making and increased productivity [1].

To be able to fulfill this goal, the key technologies driving this revolution include artificial intelligence (AI), machine learning, big data analytics and edge computing. These technologies help with predictive maintenance, self-optimizing processes and improving efficiency. Furthermore, a new concept of digital twins arose, involving the creation of virtual replicas of physical processes, production lines and supply chains, enabling the simulation and optimization of operations, improving productivity and reducing downtime [2].

To achieve this transformation, high-capacity connectivity and new modes of human–machine interaction, such as virtual reality and augmented reality, are crucial. These technologies improve human–machine interaction, making processes more efficient. The integration of these digital technologies and advanced automation creates smart, connected manufacturing facilities that enable real-time communication, remote monitoring, and data collection [3].

In short, Industry 4.0 seeks to create more efficient, flexible, responsive and predictive manufacturing processes, transforming traditional business models and supply chain management [4]. This transformation encompasses the digitalization of production processes based on devices autonomously communicating with each other along the value chain, ultimately leading to unprecedented advances in quality, reliability, and agility in manufacturing operations [5].

Industry 5.0 represents the next phase of industrial evolution, emphasizing human centricity, sustainability, and resilience as pillars of industrial transformation processes:

- Human centricity, as in putting people at the center of strategies, measuring job satisfaction, professional development and work–life balance.
- Sustainability, complying with environmental regulations and creating long-term value, ranging from emissions reduction to corporate social responsibility.
- Industrial resilience, understood as the ability to anticipate, prepare, respond and adapt to change, ensuring operational continuity and minimizing negative impacts.

The adoption of human centricity, sustainability, and resilience as the principal dimensions of the framework follows the European Commission's Industry 5.0 policy formulation. However, these dimensions are not treated as an exhaustive or universally uncontested taxonomy. Industry 5.0 remains an evolving concept whose economic, social, political, legal, and technological implications continue to be developed in policy and academic research. Accordingly, the KPI framework operationalizes a selected set of observable aspects within the three dimensions while recognizing that other relevant aspects may remain outside its current scope.

Industry 5.0 should not be interpreted as a replacement for Industry 4.0 or as a complete break with its technological foundations. Digitalization, cyber-physical systems, artificial intelligence, the Internet of Things, robotics, cloud and edge computing, data analytics, and digital twins remain relevant enabling technologies. The principal distinction lies less in the technologies themselves than in the objectives, design principles, and governance arrangements guiding their industrial application [6].

Industry 4.0 literature has not been exclusively concerned with automation and efficiency; it has also addressed human factors, sustainability, flexibility, and organizational change. Industry 5.0 nevertheless makes these considerations more explicit by placing worker well-being and empowerment, environmental sustainability, and resilience alongside productivity and competitiveness as central industrial objectives. It therefore represents

a broadening and reorientation of digitally enabled industrial transformation rather than a substitution of one technological paradigm by another.

From this perspective, the transition towards Industry 5.0 involves continuity in technological infrastructure but a change in how technological and organizational choices are evaluated (Table 1). Industrial performance is considered not only in terms of productivity, quality, cost, and efficiency, but also in terms of its effects on workers, society, environmental systems, and the capacity of organizations and value networks to adapt to disruption.

Table 1. Continuities and shifts in emphasis from Industry 4.0 to Industry 5.0.

Dimension	Industry 4.0 Foundations and Emphasis	Industry 5.0 Extension or Reorientation
Overall purpose	Digital integration, connectivity, automation, flexibility, productivity, and operational efficiency	Broader industrial value creation combining competitiveness with worker well-being, societal value, sustainability, and resilience
Technological basis	Cyber-physical systems, IoT, AI, robotics, cloud computing, data analytics, and digital integration	Builds on the same enabling technologies but evaluates and governs their use according to human, environmental, and resilience-related objectives
Role of people	Human factors, skills, supervision, interaction with automated systems, and organizational adaptation	Worker well-being, empowerment, autonomy, participation, skill development, and human–machine complementarity become explicit design priorities
Sustainability	Increasing attention to energy and resource efficiency, cleaner production, and digitally enabled environmental improvements	Sustainability becomes a central strategic objective, including circularity, life-cycle impacts, resource constraints, and environmental and social value
Resilience	Flexibility, predictive maintenance, system reliability, adaptable production, and supply-chain visibility	Resilience becomes an explicit organizational and ecosystem-level priority involving anticipation, continuity, recovery, adaptation, and learning
Organizational perspective	Smart factories, vertically and horizontally integrated production, and data-driven decision-making	Broader consideration of organizational governance, value networks, stakeholders, job quality, and long-term industrial adaptability
Performance logic	Predominant emphasis on productivity, quality, cost, speed, and efficiency	Multidimensional performance incorporating economic, human, environmental, and resilience-related outcomes
Relationship between paradigms	Provides the digital and technological foundation	Complements and reorients Industry 4.0 rather than replacing it

This reorientation also affects how industrial performance is assessed. The European Commission argues that conventional measures centered primarily on productivity and economic growth are insufficient to capture the broader contribution expected from industry. Monitoring the transition toward Industry 5.0 therefore requires indicators capable of addressing worker well-being and empowerment, environmental sustainability, and the capacity of industrial organizations and ecosystems to anticipate and adapt to disruption. However, the multidimensional nature of these objectives presents an important measurement challenge: indicators drawn from different domains may use different units, reflect different organizational levels, respond to different time horizons, and involve trade-offs that cannot be represented adequately by a single metric [7].

In this study, the three dimensions provide a shared structure for examining the two company cases. The purpose is not to assume that they can be reduced directly to one composite score, but to investigate how companies currently monitor the associated

issues, which indicators can be supported by existing organizational data, and where sector-dependent gaps or interpretation problems arise.

Studies are carried out for independent indicators, but there is a gap addressing the definition and evaluation of metrics for Industry 5.0 performance. Furthermore, in most cases, these evaluations are carried out and adapted for a single organization, which limits comparisons with other organizations and the ability to draw more objective and generalized conclusions [8], missing the opportunity to share operational experiences for effective learning. In the work by Abril-Jiménez et al. [9], an analysis of the limitations of current methodological approaches to evaluating Industry 4.0 and 5.0 processes was conducted. Issues identified include direct metrics that do not take into account the indirect contributions of workers, vertically focused metrics that overlook the reskilling and engagement of workers, and inconsistencies in key performance indicators (KPIs) between companies with different infrastructures. In addition, the fragmentation of evaluation processes hinders scalability, the sharing of best practices, and the reuse of information, especially in the case of SMEs (small and medium-sized enterprises). The lack of mature models and standardized assessments complicate the adoption of Industry 4.0 across all sectors, as well as the replication of successful practices. Proposed solutions include integrating human factors into metrics, standardizing KPIs to improve comparability, and developing scalable methodologies based on KPIs to enable wider adoption and replication. Furthermore, these assessments focus on only one of the Industry 5.0 pillars, such as human centricity [10] or sustainability [11]. In this context, the Community of Practice 5.0 emerges to pave the way for the widespread adoption of the Industry 5.0 framework in Europe. It focuses on human-centric approaches, resilience, and sustainability, bringing together a diverse group of stakeholders from the innovation ecosystem. Its main objectives are to share best practices related to Industry 5.0, co-create implementation actions, foster collaborations among industrial stakeholders, and adapt organizational models to support the green and digital transitions [4,12].

In light of all these factors, we can assure that future research directions in Industry 5.0 are vast and varied, offering numerous opportunities for exploration and growth. One key area of focus is methodological development, where incorporating survey-based approaches, simulations, and mixed-methods [13] research can enhance the rigor of the Industry 5.0 framework. Additionally, theory-driven studies should be prioritized, utilizing frameworks such as dynamic capability, institutional theory, and diffusion of innovation theory to better understand the complex interactions at play [14]. Empirical studies are also essential, particularly in exploring how the pillars of human centricity, resilience, and sustainability collectively contribute to successful Industry 5.0 implementation [15]. Furthermore, fostering multidisciplinary research integrating fields like operations and supply chain management, industrial engineering, computer science, and robotics is crucial for advancing Industry 5.0 [16]. Lastly, investigating the alignment of Industry 5.0 practices with the United Nations' Sustainable Development Goals (SDGs) is vital, with a focus on balancing economic growth with social equity and environmental sustainability.

The aim of this paper is to analyze and compare how two industrial companies operating in different sectors address the transition toward Industry 5.0 through a common KPI-based analytical framework. The selected KPIs were developed during previous stages of the PROSPECTS 5.0 project through a systematic review of academic and policy literature, stakeholder consultation, a Delphi process, and company workshops. These project activities provide the methodological basis for the framework used in the present study but are not the primary object of analysis.

The empirical contribution of the paper lies in the application of this preliminary KPI framework to a logistics company and a manufacturing company. The comparison examines

which indicators are considered relevant, which are already monitored, which data and management systems support their use, and which barriers or sector-specific limitations affect their applicability. The study therefore addresses the following research question:

RQ: How do the relevance, availability, and practical applicability of Industry 5.0 KPIs differ between two industrial companies operating in distinct sectoral contexts?

In this study, measurement refers to the observation and comparison of specific Industry 5.0-related organizational practices and outcomes through KPIs. The framework is not intended to produce a composite Industry 5.0 score, maturity level, or universal cross-industry benchmark. Instead, it provides a common analytical structure for identifying similarities, differences, and context-dependent priorities across the two cases.

The remainder of the paper is structured as follows. Section 2 summarizes the previous project activities through which the preliminary KPI framework was developed and describes the comparative case-study methodology. Section 3 presents and compares the results from the two companies and discusses the findings in relation to the literature and existing management standards. Section 4 presents the conclusions, limitations, and future research directions.

2. Materials and Methods

2.1. Origin of the Preliminary KPI Framework

The methodology reported in this paper comprises two connected but distinct stages. The first stage concerns the previous development of the preliminary KPI framework within the PROSPECTS 5.0 project. This project-level work involved contributions from several project partners and combined a systematic literature review, stakeholder consultation, a two-round Delphi study, and industrial workshops. An overview of the project-level framework development process is provided in Figure 1. Its purpose was to identify and refine a preliminary set of KPIs associated with human centricity, sustainability, and resilience.

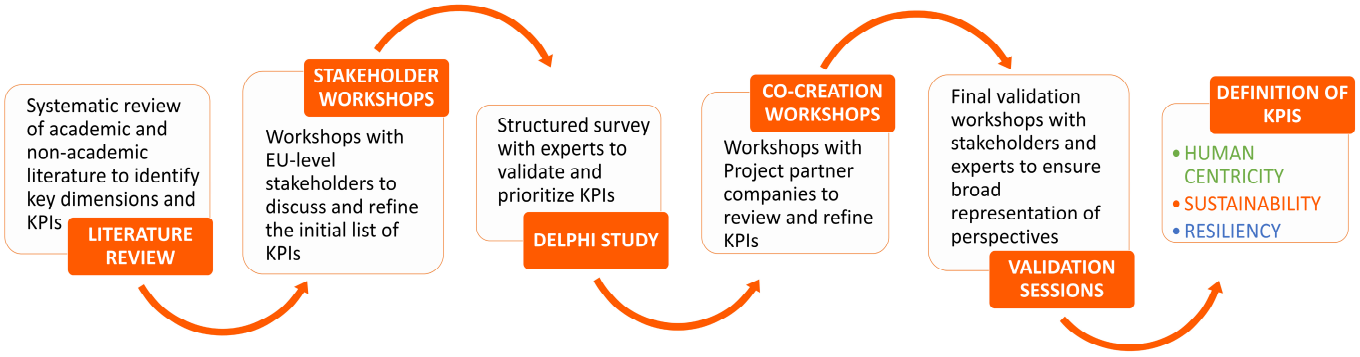


Figure 1. Overview of the project-level framework development process and the comparative case-study stage reported in this paper.

The second stage, which constitutes the empirical focus and principal contribution of the present paper, applies the resulting KPI framework to two industrial companies operating in different sectors. The literature review, Delphi study, and framework development workshops are therefore summarized in the following subsections to provide transparency and traceability regarding the origin of the analytical instrument. The present study does not independently reproduce or reassess the complete KPI development process; instead, it examines how the resulting framework operates when applied to two contrasting industrial contexts.

2.2. Literature Review Supporting the Framework Development

The preliminary KPI framework was informed by a literature review conducted during an earlier stage of the PROSPECTS 5.0 project. The review was used to identify concepts, criteria, practices, and candidate indicators associated with human centricity, sustainability, and resilience. Its role in the present study is to document the knowledge base from which the analytical framework originated [17,18].

Searches were conducted in Scopus, Web of Science Core Collection, and ScienceDirect between April 2024 and September 2024. The core search expression combined the terms "Industry 5.0", "fifth industrial revolution", and "5IR". The expression was adapted to the syntax and search fields available in each database. No restrictions were applied regarding publication year or geographical scope. The review considered English-language research articles, review articles, and conference papers for which the full text was available.

The database searches identified 879 records: 358 from Scopus, 279 from Web of Science, and 242 from ScienceDirect. The review records established the databases, core search concepts, and retrieval counts, although the complete original query history was not retained. This limitation is acknowledged because it restricts the full reproducibility of the search. To enhance reproducibility and transparency, the systematic literature review was documented following the principles of the PRISMA 2020 guidelines [17]. The screening and selection process was structured around explicit inclusion and exclusion criteria, applied consistently across all stages of the review (Table 2).

Table 2. Eligibility criteria used in the project-level literature review.

Category	Inclusion Criteria	Exclusion Criteria
Topic	Explicitly addresses Industry 5.0 or at least one of the three associated pillars	No direct relationship with Industry 5.0 or its associated dimensions
Contribution	Provides conceptual, methodological, empirical, or indicator-related information relevant to framework development	Focuses exclusively on Industry 4.0 without transferable implications for Industry 5.0
Language	Published in English	Published in another language
Publication type	Research article, review article, or conference paper	Editorial, abstract-only item, presentation, or other non-eligible document type
Availability	Full text available	Full text unavailable
Duplication	Unique record	Duplicate or overlapping record

The initial database searches yielded 879 records. Following title and abstract screening against the eligibility criteria, 284 records were retained for full-text consideration. Full-text assessment resulted in 107 eligible publications, while 177 were excluded because they did not provide sufficiently relevant conceptual, methodological, or empirical evidence for the development of the Industry 5.0 framework. Forward and backward citation searching identified 15 additional potentially relevant records. After combining the database and citation-search results, duplicate and overlapping records were removed and final eligibility was verified, resulting in 61 studies included in the qualitative synthesis [19].

The complete selection process is presented in the PRISMA flow diagram in Figure 2. The diagram distinguishes records identified through databases from records identified through citation searching and reports the number of records excluded at each stage.

Academic repositories, EU policy documents, reports from international organizations, and public deliverables from relevant European projects were also consulted as complementary sources. These materials supported the conceptual interpretation and framework

development activities but were not included in the PRISMA study count unless they had entered the formal screening process described above. This wide systematic analysis gave the opportunity to identify fundamental dimensions of Industry 5.0 and recognize gaps in existing frameworks. Key findings from the review led to the definition of 12 preliminary assessment criteria and the identification of an initial list of potential key performance indicators (KPIs). These criteria were grouped around the three core pillars of Industry 5.0. Under human centricity, the criteria included: (1) employee well-being and satisfaction, (2) health, safety, and ergonomics, (3) diversity, inclusion, and representation, and (4) employee empowerment and participation. For sustainability, the criteria encompassed: (5) environmental efficiency and emissions, (6) resource use and circularity, (7) water and waste management, (8) traceability and transparency, and (9) investment in sustainable technologies and regulatory compliance. Finally, the resilience pillar comprised: (10) risk anticipation and mitigation, (11) operational and supply-chain robustness, and (12) innovation and adaptive capacity. Together, these twelve criteria served as the conceptual foundation for identifying the initial KPI set and structuring discussions during subsequent stakeholder workshops and expert validation activities. These insights provided essential input for structuring further methodological steps, including the Delphi survey and workshops with experts.

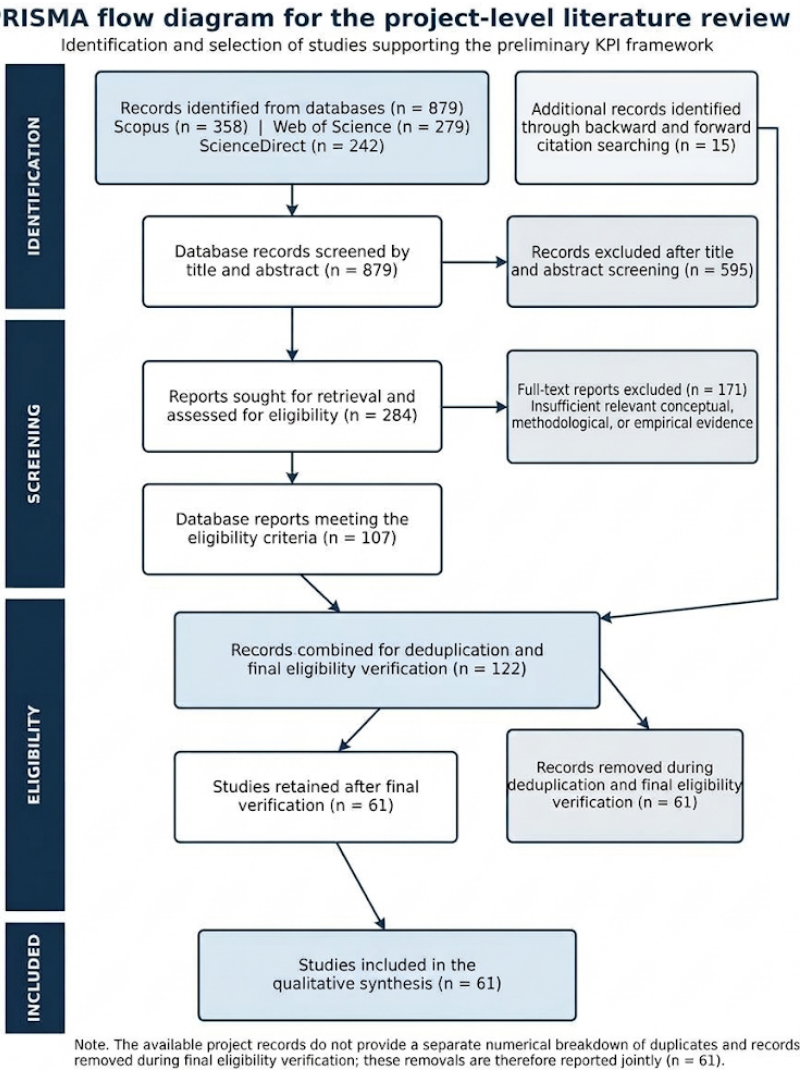


Figure 2. PRISMA flow diagram of the literature identification, screening, eligibility assessment, and final inclusion process used during the project-level development of the preliminary KPI framework.

In the second phase the initial list of potential KPIs was presented to key EU-level stakeholders, including representatives from the European Commission, EFFRA (European Factories of the Future Research Association), EIT Manufacturing, policymakers, academia, and industry leaders in a workshop held in Brussels in May 2024. These discussions provided insights into the strategic applicability of the assessment framework and helped identify missing dimensions. Stakeholders contributed to enhancing the modularity and practical relevance of the KPIs, ensuring that they could be effectively utilized in various industry contexts.

2.3. Delphi Process and Stakeholder Workshops

Following the literature review, a two-round Delphi study and a series of stakeholder workshops were conducted as part of the project-level framework development process. Their purpose was to examine expert and industrial perspectives on the main Industry 5.0 themes and to refine the preliminary analytical framework. These activities preceded the comparative company analysis reported in this paper.

- Round 1—Idea Generation:

Round 1 used open-ended questions addressing the perceived objectives, enabling factors, expected outcomes, and implementation challenges associated with Industry 5.0. The responses were reviewed and grouped thematically. Recurring themes and differences across participants were then translated into 32 statements for evaluation in Round 2.

- Round 2—Consensus Building:

In Round 2, participants evaluated the 32 statements using a five-point Likert scale ranging from 1 ("strongly disagree") to 5 ("strongly agree"). For each statement, the median, interquartile range, and response frequency distribution were calculated. Sufficient agreement was considered to have been reached when the median was greater than 3 and the interquartile range was equal to or lower than 1. Statements that did not satisfy both conditions were classified as not reaching the predefined agreement criterion.

Of the 32 statements evaluated in Round 2, 24 met the predefined agreement criterion and eight did not. Strong agreement was observed regarding the role of sustainable practices, employee digital skills, artificial intelligence, the Internet of Things, advanced data analytics, and cross-sector collaboration in the transition toward Industry 5.0. Several statements received positive median ratings but did not meet the dispersion criterion, indicating differences in interpretation or applicability across participants and sectoral cohorts. Participation was maintained at the organizational level across the two rounds. However, the available project records did not allow individual-level continuity to be confirmed for all respondents. A concise summary is presented in the following Table 3.

Table 3. Summary of the round 2 Delphi outcomes.

Result Category	Number of Statements	Interpretation
Agreement criterion reached	24	Median > 3 and IQR ≤ 1
Agreement criterion not reached	8	One or both predefined conditions were not satisfied
Total	32	Statements derived from the R1 thematic analysis

The Delphi findings informed the conceptual development of the framework by identifying areas of agreement and divergence concerning Industry 5.0 objectives, enabling factors, and implementation priorities. They did not generate numerical weights for the individual KPIs, nor did they define aggregation rules, maturity thresholds, or a composite Industry 5.0 score. The subsequent stakeholder workshops were used to translate and

discuss the project-level findings in relation to potentially observable indicators. Three stakeholder workshops were held between October and November 2024 to discuss the preliminary findings and examine the practical relevance and measurability of the proposed indicators. Across the three workshops, 77 participants were recorded, representing roles including company managers, project managers, technical specialists, and human resource professionals.

Regarding human centricity, our participants believed that Industry 5.0 should emphasize the importance of prioritizing employee satisfaction, retention, and development, ensuring work–life balance, enhancing workplace safety and wellness through ergonomic design and tools, promoting diversity and inclusivity, empowering employees with job crafting opportunities, and strengthening social connections to build a more engaged and resilient workforce.

Regarding sustainability, participants highlighted the importance of optimizing resource efficiency and minimizing environmental impact through measures such as reducing GHG emissions per unit of production, increasing the use of renewable energy, improving water and waste management, promoting circular economy principles like modularity and repairability in product design, enhancing traceability, and prioritizing investment in sustainable technologies while maintaining high regulatory compliance and exceeding environmental standards.

As the final pillar, Industry 5.0 should be characterized by strong resilience. In particular, according to our participants, this can be achieved by continuously improving risk identification, mitigation strategies, and cybersecurity response, optimizing sourcing alternatives and operational recovery times, fostering innovation through new products and services, and ensuring clear communication to maintain stakeholder confidence during disruptions.

During the workshops, one of the main ideas that emerged was that most of the KPIs presented to the companies, and which they claimed to measure, were those they associated with the ISO standards used in their organizations.

ISO standards such as ISO 45001, 9001, 14001, 59020, 30414, and 22316 [20–25] focus on various aspects of organizational performance with a strong emphasis on human-centric goals aligned with Industry 5.0. ISO 45001 [20] aims to improve occupational health and safety, while ISO 9001 [21] focuses on quality management for customer satisfaction. ISO 14001 [22] emphasizes environmental sustainability, and ISO 59020 [23] provides guidelines for assessing circular economy performance. ISO 30414 [24] supports human capital reporting for workforce sustainability, and ISO 22316 [25] enhances organizational resilience. Collectively, these standards contribute to building a more sustainable, resilient, and human-centered industrial future.

2.4. KPI Framework and Analytical Criteria

The outcome of the previous collaborative project activities was the preliminary KPI set presented in Table 4. The framework comprises indicators with different measurement characteristics. Some are directly quantitative and are expressed as counts, percentages, ratios, rates, response times, or resource-consumption measures normalized against an organizational output. Others rely on employee or stakeholder perceptions, organizational records, or documented evidence regarding the implementation and effectiveness of company practices.

Table 4. Preliminary KPI set developed within the PROSPECTS 5.0 project and used in the comparative case analysis.

Principle	KPI
Human centricity	Employee turnover rates
	Employee satisfaction rates
	Training and development opportunities
	Work–life balance satisfaction
	Number of workplace accidents/incidents
	Employee health and wellness
	Workplace ergonomic design
	Use of ergonomics tools
	Diversity ratios across workforce demographics
	Implementation of specific inclusivity programs
	Representation in decision-making roles
	Job Crafting
	Employees' perception of social connection
Sustainability	GHG emissions per unit of production/output, per employee, or per unit of revenue
	Energy consumed per unit of production output/per function or per service/per monetary unit of sales
	Use of renewable energy sources as a percentage of total energy consumption
	Water use per unit of production output/or per square meter of facility
	Waste generated per unit of production/output or per employee, and its composition
	The percentage of waste diverted from disposal
	Reduction in raw material consumption, normalized against production levels
	Percentage of products designed for Modularity, Repair, and Repurposing
	Percentage of products with traceability features implemented
	Percentage of investment in and development of new technologies aimed at improving sustainability on the total amount of investments
	Regulatory compliance rate and number of initiatives beyond compliance
Resiliency	Number of times risks occurred in the last 5 years
	Effectiveness of risk identification and assessment processes
	Number of new risk mitigation strategies implemented annual
	Local sourcing ratio
	Number of alternative sourcing options
	Average operational downtime and recovery time
	Average cybersecurity incident response time
	Number of new products/services introduced
	Personnel/Stakeholder satisfaction score on communication during and after disruptions

Note: The KPI set was developed through previous collaborative activities within the PROSPECTS 5.0 project and is used in this paper as the common analytical framework for the comparative company analysis.

Table 4 reproduces the KPI set resulting from the previous PROSPECTS 5.0 framework development activities. The present paper does not independently redefine or revalidate the technical specification of each KPI. Instead, it uses this preliminary set as a common analytical reference for examining how the indicators are interpreted and applied in two industrial companies operating in different sectoral contexts.

For each company, the analysis considered: (i) whether each KPI was regarded as relevant to the company's transition toward Industry 5.0; (ii) whether the corresponding information was already monitored; (iii) whether the data required to examine the KPI were available; (iv) whether the KPI was practically applicable given the company's activity,

size, operating model, and organizational boundaries; (v) whether an existing standard, management system, or internal process supported its use; and (vi) which implementation barriers or additional company-specific indicators were identified during the workshops.

The preliminary KPI set does not establish universal target values, maturity thresholds, or cross-industry benchmarks. The present analysis also does not introduce common normalization or weighting procedures across indicators expressed in heterogeneous units. Where a KPI already had an established definition or calculation method within a company or an applicable management system, that existing specification was retained. Where no established specification existed, the analysis was limited to examining relevance, data availability, and practical applicability rather than assigning an artificial numerical value.

Accordingly, the use of a common framework in this study refers to the application of the same preliminary KPI set and analytical questions across the two company cases. It does not imply that all indicators share a common formula, unit, target, benchmark, or aggregation method. The purpose is not to produce a composite Industry 5.0 score, but to identify similarities, differences, gaps, and context-dependent priorities in how the two companies address the three Industry 5.0 pillars.

Figure 3 summarizes the composition of the preliminary project-level KPI framework by showing the number of indicators associated with each Industry 5.0 pillar. Its purpose is descriptive: it allows the reader to observe how the current KPI set is distributed across human centricity, sustainability, and resilience. Differences in the number of indicators per pillar reflect the structure of the preliminary framework and should not be interpreted as weights, differences in pillar importance, or evidence that one pillar contributes more than another to Industry 5.0.

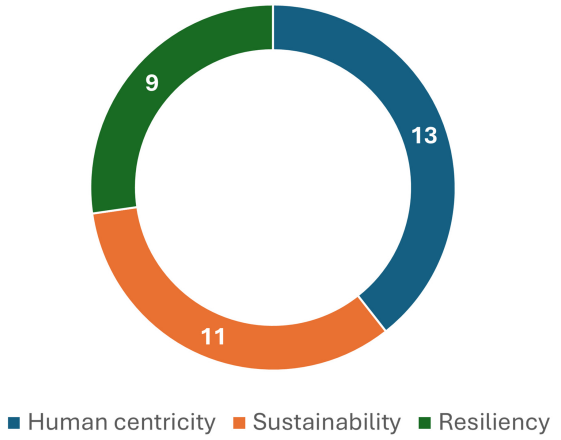


Figure 3. Distribution of the preliminary KPIs across the three Industry 5.0 pillars.

For analytical purposes, the evidence underlying the KPIs could derive from organizational records, normalized operational data, employee or stakeholder perception data, or documented organizational practices. These categories describe the type of evidence required for the case analysis and do not modify the original organization of the KPI framework.

The preliminary KPI set and the analytical criteria described above were applied consistently to both cases. The purpose was not to calculate an overall score for each company, but to identify which indicators were relevant and supported by the information provided during the company workshops and, where available, by existing organizational documentation or records, which required adaptation or additional data, and which reflected company- or sector-specific characteristics. The resulting profiles form the basis of the comparative analysis presented in Section 3. Consistency in the present study refers to the

use of the same preliminary KPI set and analytical criteria across the two cases, rather than to the standardization of the individual KPI definitions or calculation methods (Table 5).

Table 5. Analytical criteria used to examine the preliminary KPIs in the two company cases.

Analytical Criterion	Question Addressed in the Company Analysis	Evidence Considered
Relevance	Is the KPI considered meaningful for the company's transition towards Industry 5.0?	Company workshop and contextual assessment
Current monitoring	Is the KPI already measured or systematically tracked?	Organizational records, surveys, management systems or operational data
Data availability	Is the information required to examine the KPI currently accessible?	Company workshop, participant explanation, and supporting documentation where available
Practical applicability	Can the KPI be meaningfully applied given the company's activity, size and operating model?	Contextual assessment by company representatives and researchers
Supporting system or standard	Is the KPI supported by an existing management system, certification or internal procedure?	Company documentation and workshop evidence
Implementation barrier	What prevents or limits the systematic application of the KPI?	Workshop discussion and qualitative explanation
Additional indicator	Did the company identify a relevant aspect not sufficiently represented by the preliminary KPI set?	Company proposal during the workshop

2.5. Comparative Case-Study Design

The empirical stage of the study followed an exploratory comparative case-study design. The preliminary KPI framework and the analytical criteria described in Section 2.4 were applied to two industrial companies operating in different sectors: a logistics company and a manufacturing company. The cases were examined individually and subsequently compared to identify similarities and differences in KPI relevance, current monitoring, data availability, practical applicability, supporting management systems, and implementation barriers.

The unit of analysis was the company-level application of the preliminary Industry 5.0 KPI framework. The study did not seek to estimate the average behavior of companies in either sector. Instead, it used two contrasting organizational contexts to explore how the same analytical framework is interpreted and applied under different operating conditions.

For the descriptive visual comparison, the number of KPIs retained as relevant in each pillar was counted separately for each company. The values displayed in Figure 4 correspond directly to these counts. No weighting, normalization, scaling, or aggregation across pillars was applied. Consequently, the figure represents KPI coverage within the workshop results and not organizational performance, maturity, or achievement of Industry 5.0 objectives.

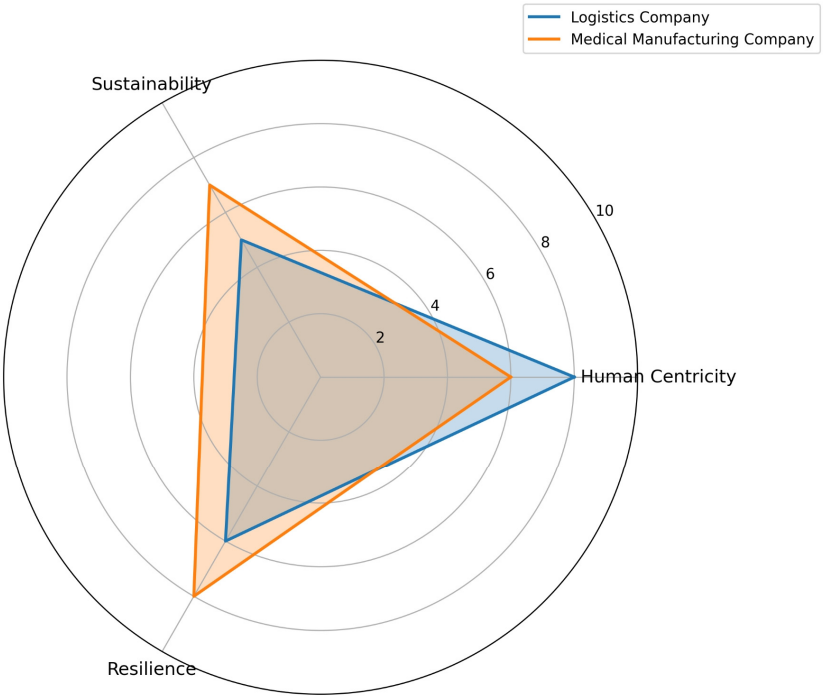


Figure 4. Preliminary KPIs retained as relevant in each company workshop, by Industry 5.0 pillar.

2.5.1. Case Selection

The two cases were purposefully selected from the 14 industrial use cases participating in the PROSPECTS 5.0 project. The selection combined analytical and practical criteria. Analytically, the companies operate in different sectors and represent contrasting business and operational contexts. The logistics company provides project-oriented services and has limited direct control over some resource and production-related variables, whereas the manufacturing company carries out production activities and has more direct interaction with material flows, operational processes, suppliers, and production resources. This contrast provides an informative basis for examining whether the relevance and applicability of a common Industry 5.0 KPI set vary across company contexts.

From a practical perspective, the two cases were those for which the authors were directly involved in the framework-application activities and had access to the corresponding workshop results and supporting information. The selection was therefore purposive rather than probabilistic. The cases are not treated as statistically representative of the logistics and manufacturing sectors.

The comparison between manufacturing and logistics is relevant because the applicability of several Industry 5.0 KPIs depends on the organization's control over production processes, resource consumption, product design, material flows, supplier relationships, and workforce organization (Table 6). Manufacturing activities may provide direct access to production, material, energy, waste, and downtime-related information, while logistics and project-based service activities may require different denominators, system boundaries, or interpretations of the same indicators. Comparing the two contexts therefore makes it possible to examine the extent to which a common KPI structure can be retained and where contextual adaptation becomes necessary.

Table 6. Characteristics of the participating companies.

Characteristic	Logistics Company	Manufacturing Company
Country	Spain	Italy
Sector/activity	Shipyards	Confidential
Company size	SME	Large Multinational Corporation
Main workshop participants	CFO, Project Manager	HR manager, Project manager, Product Manager, Sustainability manager
Date of company workshop	09/2024	07/2024
Information sources	Workshop, records, documents	Workshop, records, documents

2.5.2. Data Collection and Framework Application

The framework was applied through company workshops held in July–September 2024. The logistics company workshop involved two participants representing the Chief Financial Officer and a project manager, while the manufacturing company workshop involved 4 participants representing an HR manager, a project manager, a product manager and a sustainability manager. The involvement of participants from different organizational functions was intended to capture operational, human resource, quality, environmental, and management perspectives where these functions were available.

Each workshop lasted approximately three hours and followed the same structured sequence. The participants reviewed the preliminary KPI set by pillar and discussed the relevance, current monitoring, data availability, practical applicability, supporting systems or standards, and implementation barriers associated with each indicator. Participants could also propose additional company-specific indicators or contextual adaptations.

The principal source of evidence was the structured discussion with company representatives during the framework-application workshops. Where available, participants referred to existing management systems, certifications, surveys, internal records, or operational information supporting their responses. The study focused on whether the relevant information or measurement practice existed and how the KPI was interpreted in each context. It did not independently audit the underlying company data or recalculate every KPI from raw records.

The application began with a contextual presentation of the three Industry 5.0 pillars and the preliminary KPI framework. Company representatives then reviewed the indicators individually, considering their relevance, current monitoring, data availability, supporting organizational systems, and practical applicability. The discussion also addressed implementation barriers and possible company-specific additions. The workshop findings were subsequently consolidated into a KPI profile for each company. Differences in interpretation were discussed during the workshop, and the final company profile reflected the shared assessment reached by the participating representatives.

2.5.3. Cross-Case Analysis

The analysis was conducted in two stages. First, each company was examined independently to identify the KPIs retained as relevant, the indicators reportedly monitored, the supporting systems or information sources, the barriers to implementation, and any additional company-specific proposals. This within-case analysis preserved the organizational context in which the workshop responses were produced.

Second, the two company profiles were compared across human centricity, sustainability, and resilience. The cross-case analysis focused on: (i) indicators retained in both

companies; (ii) indicators retained in only one case; (iii) differences in current monitoring and data availability; (iv) differences associated with sector, company size, or operating model; and (v) common implementation barriers. The comparison was descriptive and did not involve statistical inference, indicator weighting, or the calculation of an overall Industry 5.0 score.

3. Results and Discussion

This section presents the application of the preliminary KPI framework to two industrial companies: a logistics company and a manufacturing company. The cases were selected from the 14 industrial use cases participating in the PROSPECTS 5.0 project because they represent contrasting operational and sectoral contexts and because the authors were directly involved in the framework-application activities conducted with both companies. The cases are not intended to be statistically representative of the logistics and manufacturing sectors. Instead, they enable an exploratory cross-case comparison of how the relevance, availability, and interpretation of a common set of Industry 5.0 KPIs vary across different organizational settings.

For each company, the analysis examines: (i) which KPIs are currently monitored; (ii) which indicators are regarded as relevant but are not yet systematically measured; (iii) which existing standards, systems, or data sources support their use; (iv) which indicators are considered inapplicable or of limited relevance; and (v) which additional indicators or implementation barriers were identified during the company workshops. The findings are first presented separately for each company and subsequently compared across the three analytical pillars.

Logistics Company

In the field of human centricity, the company is aware of its turnover data, but its quality system does not incorporate them, as it uses these data sets for purposes unrelated to turnover KPIs due to its small size. The company has a low firing rate and focuses on talent retention. It is essential to implement an evaluation system for employee development. Employees should identify their skill gaps and discuss them with their managers. They aim to achieve this by expanding the HR department.

Flexibility is established already in order to maintain work–life balance, which is why the KPI itself is not considered significant. Small companies often depend on health insurance providers for employee health and wellness. To enhance overall employee well-being, the first step the company is taking is to establish a suggestion box that ensures anonymity for all individuals. External agents conducting ISO audits ensure the company adheres to industry standards.

In any case, the main implementation barrier for human-centricity-related KPIs is that there is a need inside the company for a profile that has the capacity to manage the human resources of the company related to the development of the different employees. Furthermore, they propose to apply different percentages to people leaving the company of their own accord and to people who were fired. The main risk is the fact that there is no one with the capability to do what was mentioned before: initiate a training plan.

From the sustainability point of view, GHG emissions are not measured since the only sources are cars (both employee and company vehicles) used for commuting. However, minimizing transport usage could be beneficial for ISO 14001 compliance. Although energy consumption meets standards, it is of little importance due to its low level, and an unofficial good habits policy is in place. Companies like the use case, which do not own their buildings, often struggle to control the percentage of renewable energy used and the amount of water

consumed, especially if the building is shared with other companies. Generally, it is the final client who invests in sustainability.

Two additional KPIs are identified during the process:

1. Participation in activities and investments to fight against GHG. This will allow companies that have little margin of action to compensate for their emissions.
2. Initiatives to reduce waste and consumption. By minimizing resource use at the source, the amount of waste generated downstream is also reduced.

The main implementation barrier for sustainability-related KPIs is the complexity of the sector the company is moving in. Their approach focuses on appropriate designs adapted to existing and manufactured products, extending the service life of the machinery, and using as many standardized elements as possible.

Focusing on resilience, not being a manufacturing company, the company has struggled to find useful applications for most of the Resiliency 5.0 KPIs. Generally, suppliers are chosen for each project with several factors considered. There are three main categories: national suppliers, EU suppliers, and international suppliers.

As an additional KPI, the existence of a risk list can be useful. At the same time, lack of risk assessment plus low customer feedback are the main implementation barriers.

Within the preliminary framework, the KPIs provide a common structure for examining how company practices relate to human centricity, sustainability, and resilience. In the logistics case, their application makes it possible to distinguish between indicators that are already monitored, indicators considered relevant but not systematically measured, and indicators whose applicability is limited by the company's size, business model, operational activity, or access to data. By comparing Table 4, where all the initial KPIs are indicated, and Table 7 where the relevant ones for the use case company are listed, the workshop retained a larger number of human centricity indicators than sustainability or resilience indicators. This pattern suggests that employee-related issues were more readily connected to the company's current practices and available information within the preliminary framework. The reason for this is the actual business activity, focused on adapting to the specific needs of the client, using standard elements whenever possible, and minimizing the resources used. Ultimately, resilience is inherent in the company's environment, as adaptation to the client is the company's main premise.

Table 7. Summary of relevant KPIs identified by the logistics company.

Principle	KPI
Human centricity	Number of workplace incidents Employees perception of social connection Employee satisfaction rate Workplace ergonomic design Use of ergonomic tools
Sustainability	Waste generated per unit of production/employee Energy consumed per unit of production output/service Water use per unit of production/employee
Resiliency	Number of times risks occurred in the last 5 years

In relation to human-centricity, company representatives reported established practices and favorable conditions regarding employee retention, work–life balance, and employee health and well-being, given the track record of the current staff and the flexibility offered to its employees. Likewise, no efforts have been made or contemplated to maintain demographic diversity or specific inclusion programs (gender, ethnic or cultural), as the selection

requirements have always been purely technical and competency-based. Analyzing the nationalities and gender of the historical staff in almost all areas and functions provides contextual information relevant to the interpretation of these indicators. Indicators such as the number of accidents/incidents at work and the employee satisfaction index have already been analyzed as part of the ISO 9001 and 45001 standards, for which the company has been certified for years.

In the field of ergonomic design in the workplace and the use of ergonomic tools, ergonomics has always been considered crucial, helping to reduce risks that can lead to health problems. Other aspects such as the feeling of belonging and connectedness within the organization are currently the focus of the company's efforts. Offering more training and development opportunities to employees, as well as involving them in decision-making beyond that required by their functions, will lead to new work dynamics, new approaches to seeking opportunities, etc.

The commitment to sustainability is undeniable due to the company's own nature, since a large part of the activity and origin is based on the updating, maintenance, adaptation to new functions and regulations, and upgrading of existing machinery. Projects usually require customized designs for clients, so indicators relating to the control and reduction in emissions and raw materials do not add any more significance to the company's activity and positioning in Industry 5.0. However, significant investments have been made in new technologies to achieve more efficient designs from the point of view of raw materials and energy resources. Finally, prioritizing the use of renewable energy is not in the company's hands, given the management system of the premises.

In parallel with sustainability, resilience is considered a fundamental pillar of the use case company. Adapting to the requirements and needs of the client and its assets is one of the main goals, and being a small company makes this adaptability essential. Maintaining a supply for manufacturing is not a problem, although local suppliers are always preferred for reasons of mobility, confidence, cost and reduction in transport. The indicators derived from lack of supply or product obsolescence, for example, are not applicable in this case, but it is crucial to identify and analyze the risks that may arise in other areas. In relation to incidents and accidents that may occur, these are managed, analyzed, internalized, and mitigated whenever possible, within the ISO 9001, 14001 and 45001 standards with their corresponding certifications. These indicators are essential to ensure that the company can adapt to future changes and withstand potential future threats.

In summary, while the company focuses primarily on human-centered KPIs (such as employee satisfaction, diversity, and general well-being), it also recognizes the importance of sustainability by reducing its environmental impact and improving resource efficiency. Similarly, there is a strong commitment to resilience, with the ability to adapt to potential risks and adversity being its greatest asset.

Manufacturing company

In the domain of human centricity, the company declares that it pays particular attention to the well-being of its employees. The turnover rate is considered quite crucial, and it is systematically monitored every semester. As pointed out by human resources (HR) representatives, after the COVID-19 pandemic, many employees have reassessed their personal and professional priorities, and this increased job mobility. For this reason, understanding the motivations behind employee turnover is becoming more and more relevant. Furthermore, due to the presence of competing firms in the field, talent retention represents a relevant concern for the company. To support this goal, the company recognizes the importance of monitoring employee satisfaction. Currently, HR representatives are open to dialog with employees, and an anonymous suggestion box is provided, ensuring anonymity for all

individuals. However, the company is considering implementing a structured methodology to capture employee satisfaction in a more systematic and standardized way.

Closely linked to job satisfaction particularly, after the pandemic, the company considers the promotion of work–life balance as a crucial variable. To foster employee well-being and long-term engagement, the company has introduced flexible working hours and initiatives such as short Fridays and hybrid working. However, the efficacy and the impact of these activities are not measured yet.

To maintain and increase employee commitment, the company invests in employee training and development. Structured training plans and personalized annual programs are established for employees across different departments, including production and administration. While these initiatives are well-established, the evaluation of their long-term impact on employees' job satisfaction and commitment remains an area for improvement.

In the field of health and wellness, the company does not have programs or specific activities; instead, it offers an open-door service once a week where employees can discuss issues related to their working activities.

The company underlines the importance of employee health and safety by maintaining secure working environments; to reach these goals, it offers targeted training and appropriate equipment and ensures compliance with safety regulations. Moreover, safety indicators, such as the frequency and nature of workplace accidents and incidents are systematically monitored. This encompasses all reported events—whether resulting in injury, classified as near misses, or involving robotic systems, cyber-physical technologies, or human error—within a defined reporting period.

In line with the above, the ergonomic design in the workplace and the use of ergonomic tools are also considered important and are systematically evaluated through standardized evaluation protocols and checklists, accompanied by employee surveys to gather feedback on comfort, satisfaction, and potential ergonomic concerns. Also job crafting practices as a means of enhancing employee satisfaction and productivity are encouraged.

The company recognizes the importance of promoting diversity, inclusion, and participatory governance: it monitors diversity indicators—such as gender, ethnicity, age, and disability—and promotes fair representation in leadership roles. Although the company has not implemented a specific inclusivity program, the suggestion box provides employees with an opportunity to share ideas and express concerns related to inclusivity and workplace improvement. Finally, the company does not currently assess employees' perceptions of social connection. However, especially in the aftermath of the pandemic, it has organized informal events involving employees and their families.

The workshop also led to the identification of employee absenteeism as a valuable additional KPI, highlighting its potential role in assessing organizational health and productivity.

Considering the second pillar—sustainability—the company declares a strong and proactive commitment to environmental responsibility and sustainable development. In particular, the company employs the WeSustain platform and follows GRI standards to track and report on its performance. Regarding GHG emissions, the company adheres to the standards required by the GRI, monitoring electricity, steam, and gas consumption. Similarly, energy consumption is evaluated in accordance with GRI guidelines, with data being reviewed on a quarterly basis. For the use of renewable energy sources as a percentage of total energy consumption, the data are collected via the WeSustain platform and energy management systems. The company monitors water usage using sector-specific benchmarks. Waste generation is monitored, with detailed tracking of its composition. In addition, the company reports that 95–96% of materials—including packaging and manufactured products—are recycled, while hazardous waste is managed through incineration.

The percentage of waste diverted from disposal—through practices such as recycling and reuse—is systematically calculated and managed via the WeSustain platform. The reduction in raw material consumption, normalized against production levels, is tracked using GRI parameters and managed through the WeSustain platform. The company monitors the percentage of products designed for modularity, reparability, and repurposing using tools such as Product Life Cycle Assessment (PLA) and Life Cycle Assessment (LCA). Regarding the percentage of products featuring traceability, the company specifically refers to the use of RFID standards and blockchain technology.

The company evaluates the percentage of investment in and development of new technologies for improving sustainability through financial records. Compliance with environmental regulations and the implementation of voluntary initiatives are tracked using ISO standards (14001, 45001, 50001).

Focusing on the third pillar, the company considers resilience an important and necessary aspect to address the challenges of Industry 5.0. In particular, the number of key risks and the effectiveness of risk identification are monitored through tools and standards such as UNI 7249. This process is considered highly relevant for both employee safety and production efficiency. The implementation of mitigation strategies, including ergonomic redesign, safer tools, and environmental adaptation is considered a critical variable for long-term resilience and is integrated into investment planning. For the company, local sourcing is becoming increasingly important due to geopolitical uncertainties, and it is considered crucial for the company's future. Moreover, the company faces numerous challenges in diversifying alternative sourcing options. For this company, there are stringent regulatory and certification requirements, which often make this process difficult to implement. This difficulty represents a significant challenge, making the implementation of this KPI relevant but difficult to execute. As regards business continuity, the company considers tracking the average operational downtime and recovery time by employing different strategies to be relevant.

The company acknowledges the importance of tracking cybersecurity incident response times, but at the moment, it is not measured. Also, the number of new products/services introduced is not currently tracked, but this is a potential KPI in the future. Finally, satisfaction with internal and external communication during and after disruptions is not tracked, as it is considered difficult to measure and implement.

By comparing Table 4, in which all the initial KPIs are indicated, and Table 8, where the relevant KPIs for the use case company are reported, it is clear that the company has a strong awareness of the strategic value of the principles of the three pillars, human centricity, sustainability and resilience, that define the Industry 5.0 paradigm.

Regarding human centricity, the company shows a strong commitment to employee well-being. However, some challenges are reported in terms of systematic measurement and the use of an adequate methodology for data collection. The barriers to implementation are limited time, insufficient resources, and the complexity involved in analyzing large volumes of data.

In terms of sustainability, the use case shows a structured approach; almost all the KPIs are measured and tracked using platforms like WeSustain and GRI standards. Moreover, it demonstrates strong attention to recycling and circular design principles.

Finally, the company recognizes the role of resilience, particularly the relevance of risk management, local sourcing, and operational continuity. Some KPIs, such as cybersecurity response time, are not yet implemented, but their critical role is acknowledged. Some barriers to implementing certain KPIs are due to regulatory constraints in the operating sector of the company, which make sourcing diversification quite difficult.

Table 8. Summary of relevant KPIs identified by the manufacturing company.

Principle	KPI
Human centricity	Employee turnover rates
	Employee satisfaction rates
	Training and development opportunities
	Work–life balance satisfaction
	Number of workplace accidents/incidents
	Employee health and wellness
	Workplace ergonomic design
	Use of ergonomics tools
	Diversity ratios across workforce demographics
	Representation in decision-making roles
	Job Crafting
Sustainability	GHG emissions per unit of production/output, per employee, or per unit of revenue
	Energy consumed per unit of production output/per function or per service/per monetary unit of sales
	Use of renewable energy sources as a percentage of total energy consumption
	Water use per unit of production output/or per square meter of facility
	Waste generated per unit of production/output or per employee, and its composition
	The percentage of waste diverted from disposal
	Reduction in raw material consumption, normalized against production levels
	Percentage of products designed for Modularity, Repair, and Repurposing
	Percentage of products with traceability features implemented
	Percentage of investment in and development of new technologies aimed at improving sustainability on the total amount of investments
	Regulatory compliance rate and number of initiatives beyond compliance
Resiliency	Number of times risks occurred in the last 5 years
	Effectiveness of risk identification and assessment processes
	Number of new risk mitigation strategies implemented annual
	Local sourcing ratio
	Average operational downtime and recovery time

The two cases provide an initial practical application of the framework rather than a definitive validation of the KPI set. Their contribution lies in showing how the indicators are interpreted, supported by existing organizational practices, and constrained by sector- and company-specific conditions.

The comparison of the two cases reveals three main patterns. The results show differences in the number and type of KPIs retained as relevant in the two workshops. The logistics company retained a more selective set, particularly in sustainability and resilience, reflecting its project-based service activity, smaller organizational scale, and limited direct control over some production- and resource-related variables. The manufacturing company retained a broader set of indicators across the three pillars, supported by its production activities, existing management and reporting systems, and access to a wider range of operational information. The cross-case results indicate substantial differences in the number and type of KPIs considered relevant and available in the two companies. Figure 4 summarizes these differences by reporting the number of KPIs retained for each company within each pillar. These values are direct counts derived from the company-specific KPI tables. They were not normalized, weighted, or aggregated into an overall score. The figure should therefore be interpreted as a descriptive representation of KPI coverage in the two

workshops, rather than as evidence that one company performs better or has reached a higher level of Industry 5.0.

4. Conclusions

This study examined how the relevance, availability, and practical applicability of a preliminary Industry 5.0 KPI framework differed between two industrial companies operating in distinct sectoral contexts. The findings show that the same analytical framework can support a structured comparison, but its application is strongly influenced by company activity, size, operating model, organizational boundaries, existing management systems, and access to information. The study therefore supports the use of a common analytical structure while also demonstrating the need for transparent contextual interpretation.

The logistics company retained a more selective set of indicators, particularly in sustainability and resilience, reflecting its project-based service activity and limited direct control over some production- and resource-related variables. The manufacturing company retained a broader set across the three pillars, supported by its production activities and access to a wider range of operational and reporting information. These differences represent variations in KPI relevance and availability within the two cases and should not be interpreted as evidence that one company performs better or has achieved a higher level of Industry 5.0 implementation.

The two cases also show that existing management standards, certifications, surveys, reporting systems, and internal procedures can provide useful information for examining Industry 5.0-related practices. However, the existence of these systems or compliance with a standard does not by itself demonstrate the achievement of Industry 5.0 objectives. Existing indicators provide a practical starting point, although they may require reinterpretation, complementary information, or adaptation to connect them explicitly with human centricity, sustainability, and resilience.

The contribution of the study lies in the company-level application and comparison of a common preliminary KPI framework. It does not provide a universal Industry 5.0 index, maturity model, or benchmarking system. Instead, it identifies practical differences between KPI relevance, current monitoring, data availability, and organizational control. This distinction is important when indicator frameworks developed at the conceptual or project level are applied in operational company contexts.

Several limitations should be considered when interpreting the findings. First, the empirical analysis is based on two companies selected purposively from the 14 industrial use cases participating in the PROSPECTS 5.0 project. The cases provide contrasting organizational contexts but are not statistically representative of the logistics and manufacturing sectors. Second, the principal evidence was obtained through structured company workshops and supporting organizational information where available. The study did not independently audit all underlying records or recalculate every KPI from raw data. Third, the inclusion of a KPI in a company profile indicates that it was retained as contextually relevant; it does not necessarily indicate systematic monitoring, a favorable KPI value, or achievement of the corresponding Industry 5.0 pillar. Fourth, the current framework contains indicators with heterogeneous units and evidence types and does not establish common weights, normalization procedures, maturity thresholds, or industry benchmarks. Finally, the preliminary KPI set does not operationalize every possible aspect of human centricity, sustainability, and resilience.

Future research should extend the empirical application to additional companies, sectors, company sizes, and geographical contexts. Longitudinal studies are also needed to determine whether the indicators are sufficiently sensitive to organizational change and can support the monitoring of progress over time. Further framework development

should clarify KPI specifications, data quality requirements, organizational boundaries, and the distinction between indicators of policy or capability and indicators of observable outcomes. It should also examine whether a limited core set can be applied consistently across industrial contexts while additional indicators are adapted to sector- and company-specific conditions. Weighting procedures, maturity levels, composite scores, and industry benchmarks should only be considered after broader empirical application and appropriate evaluation of measurement validity.

Overall, the findings show that a common KPI framework can facilitate structured reflection and comparison across companies, but meaningful Industry 5.0 assessment requires contextual interpretation, transparent evidence, and a clear distinction between indicator availability and actual organizational achievement.

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