DEVELOPING INDUSTRY 5.0 TO EFFECTIVELY HARNESS PRODUCTION CAPACITIES

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Abstract:
The dynamic evolution of the economy and the evolving demands necessitating adaptability are primary catalysts for the emergence of Industry 5.0 which, building on the foundations of Industry 4.0, is oriented towards meeting human needs and expectations while ensuring the responsible functioning of the workforce. This is particularly salient in sectors experiencing rapid advancements in manufacturing concepts, characterized by the integration of advanced IT, information and data utilization, automation, and the deployment of collaborative robots, often referred to as “cobots”. The study outlines the key prerequisites concerning the development and operation of Industry 5.0, as specified in European Union guidelines, and evident in research literature. Three critical facets pertinent to the effective implementation of Industry 5.0 are extensively addressed, encompassing the imperative to effectively cater to human-related requisites and highlighting the potential benefits therein. The paper offers an overview of openly accessible, previously published materials on the subject. The author's examination encompasses studies regarded as milestones, which build on the foundations of Industry 4.0 to advance the conceptual framework of Industry 5.0. Rather than centering on statistical analysis, this research attempts to explore relationships that warrant further in-depth investigation to ascertain existing correlations. The paper seeks to outline factors to be considered in the course of implementing Industry 5.0. Its conclusions may be of use in supporting people responsible for organizational development and specifically in helping them to identify potential issues so as to give their organization an edge in the global competitive environment.

Key words: Human-centric shaping of actions, Industry 5.0, Production efficiency

INTRODUCTION
The effort to align the industrial landscape with today's needs is an inherent aspect of the evolution of industry. Shifting operational paradigms requires the deployment of suitable solutions. The notion of Industry 5.0 can be considered a new concept complementing Industry 4.0. The fundamental alterations to Industry 4.0 are rooted in the imperative to accommodate the needs of the workforce, recognizing workers as essential contributors to production. Industry 4.0 refrains from over-emphasizing environmental, social, and even human health and safety metrics. Instead, it posits a significant shift in approach by positioning human well-being at the heart of manufacturing systems [1, 2]. Industry 5.0 does not seek to entirely overhaul the existing industrial framework [3, 4]. Instead, it emphasizes the harmonious coexistence of machines and humans as collaborative entities, rather than competitors [5, 6]. On the one hand, it accentuates the significance of the skills, knowledge, and capabilities of workers, fostering collaboration among humans, robots, and other machines. On the other, it enhances the adaptability of manufacturing processes while safeguarding the production environment [4, 7]. This requires competence improvements, particularly in occupations that are vanishing, at risk, or that need to be transformed into other professions that are in high demand [8] as a proactive measure to address emerging challenges [9].

Industry 5.0 integrates cutting-edge technologies, including artificial intelligence, the Internet of Things, and Big Data, with more traditional manufacturing processes, placing a great deal of focus on human actors. After all, the success of implementation projects relies heavily on human involvement and human-related benefits. These adaptations are prompted by the rapid proliferation of new technologies and a growing reliance on robotics. According to data from the International Federation of Robotics (IFR), the United States witnessed a 20% surge in the deployment of industrial robots between 2017 and 2018 [10]. It is noteworthy that industrial robots are now deployed across a diverse range of industries, making it increasingly challenging to identify a single industry at the forefront of robotic application.
The swift and multifaceted adoption of robots in production fuels transformations that foster enhanced collaboration between humans and machines. Moreover, it underscores the imperative of waste reduction and loss prevention. Consequently, the primary emphasis within the ambit of Industry 5.0 revolves around effectively harnessing the production capacities of both machines and human workers through synergistic interactions. These synergies are pivotal for maximizing the utility of technological assets, marking a shift from the virtual realm to the physical world, thereby capitalizing on the benefits of continuous collaboration [6, 11]. In contrast to Industry 4.0 which emphasizes volume and mass production, Industry 5.0 prioritizes high-value roles, creativity, and the production of bespoke high-quality products.

Despite an extensive body of research on the topic, the available findings remain incomplete. The majority of scholars fail to adopt a comprehensive approach to examining the factors that influence the practical implementation of Industry 5.0, particularly in the context of sustainable production. In light of this observation, the author attempts to structure the factors that can be associated with specific conditions, constraints (disruptions), and potential advantages. While Industry 5.0 has garnered significant attention and holds great significance for sustainable growth, it is important to note that the mechanisms enabling this concept to add value in social and environmental terms are largely under-researched. This deficiency has been addressed as a set of research problems. Special consideration has been given to unexplored areas of research, such as integrated sustainable development from a human perspective and the resilience of systems in relation to the factors that promote and impede technology deployments.

GUIDELINES FOR SHAPING THE INDUSTRY 5.0

The term “Industry 5.0” made its debut in 2017 when Esben H. Østergaard, the CEO of REInvest Robotics, first coined it. The comprehensive vision of Industry 5.0 was subsequently crystallized in 2021 through the European Commission report titled “Industry 5.0” [12]. As per this concept, Industry 5.0 represents an evolutionary stage in manufacturing approaches where machines attain a level of intelligence enabling them to independently execute complex operations with the aid of advanced technologies and robust computing capabilities.

Achieving this necessitates securing opportunities for growth that can align with both human requirements and the demands of the technological landscape. Among the many benefits to be realized, it is worth emphasizing the promotion of sustainable development [13, 14, 15], which, in turn, ensures the efficient operation within the production environment [9, 16, 17]. The literature acknowledges that technological innovations and their industrial applications may align with the core objectives of sustainable manufacturing.

Industry 5.0 strives to establish an enhanced equilibrium between technical machinery and human labor. This can be perceived as a human-centered perspective on the technological transformations unfolding in the industrial sector, harmonizing the present and future requirements of both workers and society at large, while optimizing energy consumption, material processing, and product life cycles in a sustainable manner. This approach facilitates a transition towards sustainable growth [17, 18, 19]. Industry 5.0 represents an evolving approach that responds to ongoing advancements in industrial technology. This paradigm aims to optimize business operations, especially where the implementation of Industry 4.0 guidelines is unfeasible due to environmental constraints and limited external influences [20]. Industry 5.0 signifies a stage of production wherein machines achieve the intelligence required to autonomously execute complex tasks, leveraging advanced technologies and powerful computational capabilities. The resultant efficiencies are primarily harnessed to facilitate collaboration with humans, thereby expediting and refining task execution to better fulfill needs and expectations. This progressive development yields increased efficiency and cost reduction in business operations [6]. Industry 5.0 enables the harnessing of human creativity in collaboration with efficient, smart, and precise machines, thereby conserving resources and deploying user-preferred solutions [3, 21, 22]. However, the attainment of such efficiency hinges on the acknowledgement of prevailing needs, including the need for developing new competences [8].

Industry 5.0 is centered on delivering products and services that improve the quality of life for the general populace while personalizing interactions with machines and AI-driven systems. This approach underscores sustainability and the advancement of the bioeconomy. A human-centric philosophy positions human needs and interests at the heart of the production process. The foremost objective is to place an emphasis on people [15]. This pertains not only to protecting a person’s physical health in the workplace but also to upholding people’s mental health and well-being [1, 2].

Technology is envisioned as a means to serve people and society, necessitating production solutions to cater to the needs of a diverse workforce. This requires the development and application of circular production models, enabling the reuse, repurposing, and recycling of natural resources, the reduction of waste, mitigation of adverse environmental impacts, and ultimately the creation of an economy that optimally utilizes resources, rendering industrial production more resilient to disruptions and better capable of sustaining critical infrastructure during crises. The future industry must possess sufficient resilience to disruption to adapt swiftly to (geo)political shifts and emergencies [4, 7, 12, 23].

RESEARCH PROBLEM

A review of management science literature reveals limited attention in the research community being given to Industry 5.0, in contrast to extensive research on prior industry concepts. This discrepancy persists despite the substantial potential of Industry 5.0, primarily attributable to its emphasis on the human factor. The fundamental tenets of Industry 5.0 place significant importance on the role of workers. Given the intimate relationship between management sciences and practical business applications, solutions within this realm should yield specific implications for
business practice. The essence of this approach lies in acquiring the necessary knowledge to:

- Determine the requirements for facilitating a smooth transition from preceding industry paradigms to Industry 5.0,
- Explore pivotal technologies for enhancing industry processes,
- Identify challenges and opportunities presented by the emerging industrial revolution.

Drawing upon these observations, the author identifies and delves into research problems discussed and scrutinized in subsequent sections of the paper. The analysis relies on existing research on Industry 4.0 and Industry 5.0, with the latter being perceived as an extension of the preceding Industry 4.0 concepts, predominantly found in publicly accessible articles. Studies shorter than two pages have been omitted.

Three main research problems (RPs) are thoroughly examined, and the questions are answered:

**RP1: Prerequisites for successful implementation regarded as guiding principles for the operation and progression of Industry 5.0.**

- What prerequisites are essential for the successful implementation of Industry 5.0 guidelines?
- Given the nature of the endeavor, it is imperative to establish the relationship between such prerequisites and the roles of human actors as both active contributors and subjects within production processes.

**RP2: Prevailing deployment constraints that affect successful implementation and necessitate identifying practical aspects in implementing the requirements of Industry 5.0.**

- Which aspects of Industry 5.0 implementation are critical for effectively adhering to Industry 5.0 principles?

**RP3: Reason and motivation for embracing solutions aligned with Industry 5.0 based on the benefits they offer:**

- What is the aim of implementing Industry 5.0?
  As previously mentioned, it is vital to determine the nature of the benefits to be acquired and therefore essential to establish:
  - Whether the benefits of adopting 5.0 can be identified?
  - And what such benefits are?

**FINDINGS AND DISCUSSION**

**Guidelines for operating and developing Industry 5.0**

The fundamental premise of Industry 5.0 revolves around automating processes while reducing the need for human involvement, ensuring the fulfillment of the needs and expectations of human workers, and facilitating their effective participation. Although organizations strive to automate production to the fullest extent possible, they invariably discover that human involvement remains indispensable for their operation. Industry 5.0 seeks to strike a balance between the utilization of technical devices and human labor. It is underpinned by three fundamental pillars [4, 24]:

- A human-centric approach that positions human needs and interests at the heart of the production process,
- Sustainability, which mandates the adoption of a circular production model to utilize resources efficiently, encompassing environmental protection, green energy, sustainable consumption of goods, and the satisfaction of human needs to preserve resources for future generations,
- Resilience achieved by mitigating the impact of geopolitical shifts, crises and challenges arising from globalized collaboration.

To effectively achieve these objectives, innovative solutions that redefine human functioning in these new environments must be embraced. Their attributes are presented in Table 1.

<table>
<thead>
<tr>
<th>Pillars of Industry 5.0</th>
<th>People</th>
<th>Organization</th>
<th>Technology</th>
</tr>
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<tbody>
<tr>
<td>Human-centrism</td>
<td>Ensuring human collaboration with technical equipment, and specifically the effective use of workers’ physical, sensory, and cognitive capabilities.</td>
<td>Employing ergonomics (physical, cognitive, and organizational paradigms) and digitalization to improve the quality of working environment.</td>
<td>Adapting technology to human needs. Special attention given to proper human-machine interactions.</td>
</tr>
<tr>
<td>Sustainable growth</td>
<td>Taking into account the competences of people capable of managing change (moving from technology to solutions and from solutions to operations). Establishing new workstations based on interdisciplinary knowledge that recognizes stakeholders needs and expectations.</td>
<td>Application of new business models that recognize the impact of actions on sustainability of environmental, social, and economic development. Use of effective support tools (such as lean management)</td>
<td>Ensuring efficient use of resources and reducing energy consumption. Use of waste generated during processes. Actions that enable ongoing assessment of the effectiveness of resource consumption cuts.</td>
</tr>
<tr>
<td>Distortion resilience</td>
<td>Recognizing people as key process input that can potentially be first to detect irregularities. Seeing training and education as key development factors that help improve skills, build awareness, and ensure leadership.</td>
<td>Using organizational skills, procedures, practices, and processes. Deployment of risk reduction plans and effective prevention techniques. Using production collaboration networks.</td>
<td>Decentralizing flow networks. Ensuring integration of information that connects various industry segments and levels and processes (by employing smart platforms to improve the effectiveness of collaboration networks). Ensuring protection and proper sharing of data and information.</td>
</tr>
</tbody>
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**Table 1**

**Key factors for the effective implementation of Industry 5.0**

(Source: based on [4, 24].)
Solutions aimed at meeting the requirements outlined in Table 1 are primarily geared towards acquiring the capacity for data collection and aggregation. This endeavor typically entails the use of advanced simulations, machine learning, and historical data analysis. Such systems serve as a response to application architectures characterized by the dispersion of data across multiple systems and databases. In this context, Industry 5.0 complements Industry 4.0. It sees research and innovation as a force propelling the transition towards a sustainable, human-centric industrial landscape. Industry 5.0 not only acknowledges the pivotal role of new technologies in fostering prosperity beyond mere job creation and economic growth but also places paramount importance on the well-being of workers. Alongside its technical capabilities, Industry 5.0 underscores the significance of harnessing worker intelligence, recognizing workers as the vital missing ingredient in operational processes. Consequently, it combines the precision of machines with the creativity and ingenuity of human beings.

In the course of manufacturing, a transformation takes place in which new technologies significantly impact workers in their specific environment, whether they are viewed as active participants in the production process or as end-users who require the delivery of tailored products [5, 24]. Effective progress is unattainable without acknowledging the central role of the human factor [7]. By affording the human factor its due importance, Industry 5.0 profoundly restructures human-centric requirements in the realm of production, benefitting all stakeholders throughout the organization.

To ensure the effectiveness of actions, manufacturers must respond promptly to evolving circumstances, which, in turn, requires unfettered access to pertinent information. To enable this, avenues must be created to for individuals to articulate their needs and expectations. This transition encompasses a shift from physical to cognitive work, enabling the execution of value-added production tasks while operating alongside an autonomous workforce comprising perceptive and well-informed collaborative robots that understand human intentions [25]. This process is facilitated by the deployment of digital activity descriptions that enhance the efficiency of traditional production processes while elevating performance quality.

**Practical considerations for realization the requirements of Industry 5.0**

The effective operation of Industry 5.0 requires not only the use of internal company data and information, but also entails the sharing of data with external environments. The resulting relationships are shown in Figure 1. The primary challenge at hand is to identify essential information that is necessary for consistent operations [12]. Industry 5.0, which combines man and machine, helps better harness the power of human mind and creativity to enhance process efficiency by the integration of workflows with smart systems. Industry 5.0 benefits from the synergy between humans and autonomous machines, which must be "perceptive" and "well informed" about human intentions and desires. This ensures efficient production, bolsters confidence in autonomous systems, and reduces waste and the associated costs.

To best recognize human needs and expectations, a new approach is needed that will improve human-machine communication, a pivotal facet for the optimization of production. A range of options is available for achieving this objective. Industry 5.0 helps align individual capabilities with the requisites of AI, while deepening human-machine interactions through machine learning. This invariably catalyzes the rapid advancement of AI, which, in turn, augments data analysis and enhances communication between human operators and technological devices, irrespective of their configuration. As a consequence, the solutions adopted significantly improve a company’s ability to operate effectively. However, one should underscore that the chosen solutions must be tailored to accommodate the specific needs and expectations of stakeholders, calibrated to each individual participant engaged in operations. Thus, the domain of Industry 5.0 technologies calls for transformative adaptations that engender efficient human-machine collaboration, ultimately culminating in marked enhancement of performance efficiency [3]. Realizing these desired effects hinges on rational development, ensured by embracing the findings of prior observations [20, 26, 27]. An essential prerequisite mandates the harmonization of all activities to extract optimal benefits at the intersection of the virtual and physical worlds. A comprehensive overview of the requisite human attributes and their interplay with machines, indicative of their personalized nature, is presented in Table 2.

The attributes given in Table 2 help one take advantage of practical opportunities that are essential for executing human-centric activities. These encompass the preservation of sustainable growth, including environmentally friendly practices, the adoption of green energy, and the promotion of sustainable consumption, all the while addressing human needs in a manner that guarantees the availability of resources for future generations and fortifies resilience to ongoing geopolitical dynamics and potential crises that could disrupt global collaboration.
The primary aim of this improvement loop is to eliminate or reduce the waste generated during the execution of work tasks. Many of the resulting benefits come directly from reductions in the number of tasks allocated to human workers, subsequently delegating tasks to machines where their efficiency surpasses that of humans. A notable example of such a solution is the use of collaborative robots (cobots) [25, 28]. Being based on AI, cobots are designed specifically to collaborate with humans and are crucial for the rise of Industry 5.0. Essential to the function of cobots is the establishment of uncomplicated interactions with humans, serving both to set production objectives and ensure safety. Smart devices analyze human-performed tasks, finds the methodologies employed by humans, and ascertain their objectives. Such activities are subsequently assessed for opportunities to augment operator performance. The ensuing benefits include the ability to expedite and optimize task execution, or having the complex tasks performed autonomously by machines through the use of advanced technologies and available computing capabilities.

### The aim of Industry 5.0-conformant solutions and their benefits

Improving the working conditions for production tasks, informed by the appreciation of human capabilities and predispositions, brings numerous benefits for all stakeholders. These advantages stem from the alignment of the technological environment with human requirements. Empirical evidence shows that the automation of production processes can reduce production costs, improve production quality, and streamline logistics. This is most commonly facilitated through the effective harnessing of digital technologies, resource management optimization, and the efficient oversight of industrial product manufacturing. Once these benefits are achieved, it becomes imperative to stay this course of development, which means exploring new, superior solutions founded upon the synergy between humans and machines [21]. To secure such benefits effectively, an adaptive approach is needed that will ensure compliance with requirements and integrates human actions into the process architecture. To that end, a range of tools may be employed, including edge computing (EC), digital twins (DT), collaborative robots, the Internet of Everything (IoE), Big Data, blockchain, and 6G systems [3]. As a result, the benefits of both Industry 4.0 and Industry 5.0 are maximized while circumventing their respective limitations [25]. This affords great resilience to systems that straddle the digital and human realms, facilitating the implementation of solutions in alignment with the tenets of Industry 5.0. In turn, solutions consistent with the principles of Industry 5.0 engender a more environmentally friendly operational landscape. This is achieved by:

- RECONSIDER the available solutions,
- REALIZE the selected options,
- REDUCE resource consumption loads,
- REUSE viable residues,
- RECYCLE resources that cannot be repurposed.

### Table 2

**Interplay between man and machine required to attain symbiosis, as prescribed by Industry 5.0**

<table>
<thead>
<tr>
<th>Value of human workers</th>
<th>Requirements to be met to realize value</th>
</tr>
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<tbody>
<tr>
<td>Self-development</td>
<td>Enabling employees to achieve their goals and, consequently, succeed by demonstrating abilities and competences that contribute to their effective functioning in a technical environment.</td>
</tr>
<tr>
<td>Responsibility</td>
<td>Ensuring full transparency of actions and decisions based on the causes (sources) of non-conformities.</td>
</tr>
<tr>
<td>Credibility</td>
<td>Ensuring that tasks can be performed in an honest, trustworthy, and reliable manner, where response time is of the essence, using a hybrid human-machine system.</td>
</tr>
<tr>
<td>Privacy</td>
<td>Ensuring the privacy of the information provided by only using unrestricted data having obtained the informed consent of all concerned parties.</td>
</tr>
<tr>
<td>Prosperity</td>
<td>Ensuring an environment that fosters the physical and mental well-being of workers. Taking advantage of work-life balance, defined as optimal workload and a worker-friendly working environment.</td>
</tr>
<tr>
<td>Autonomy</td>
<td>Allowing workers to perform autonomously, freely, and flexibly by making independent choices and employing their creativity and intelligence.</td>
</tr>
<tr>
<td>Altruism</td>
<td>Increased emphasis on teamwork, ensuring the well-being of all individuals with whom the worker comes into contact in the course of performing work.</td>
</tr>
<tr>
<td>Common good</td>
<td>Ensuring worker well-being in a sustainable working environment.</td>
</tr>
<tr>
<td>Security</td>
<td>Ensuring that workers can perform their work safely in orderly, stable, and harmonious work relationships and physical environments.</td>
</tr>
<tr>
<td>Stimulation</td>
<td>Solutions that promote worker improvement by assigning tasks that require continuous learning and that ensuring professional growth.</td>
</tr>
<tr>
<td>Social relationships</td>
<td>Ensuring good social relationships and interactions with colleagues, allowing workers to function well in their social environment.</td>
</tr>
<tr>
<td>Identity</td>
<td>Taking actions that ensures equal opportunities for all, avoiding discrimination and enabling control over events and actions.</td>
</tr>
<tr>
<td>Authority</td>
<td>Empowering workers, improving their social status, and enabling them to better oversee other members of the organization and make effective use of available resources.</td>
</tr>
<tr>
<td>Conformism</td>
<td>Supporting workers to comply with rules and satisfy expectations of functioning in their environment by choosing solutions that are consistent with existing situation.</td>
</tr>
</tbody>
</table>

Source: based on [5].

A prerequisite for optimizing performance is the acknowledgement of human capabilities during the system design phase [7, 28]. It is judicious to anchor the deployment of Industry 5.0 within the framework of the 6R principles in an improvement loop, which entails the following steps:

- RECOGNIZE the problem,
- Enhancing business models and ensuring the profitability-inducing solutions that bolster operational efficiency enhancing the bottom line,
- Increasing reliability, extending product life cycles to ultimately conserve natural resources,
- Ensuring IT security and operational safety in the use of machines and reducing hazards to humans, leading to more efficient operations and lower air pollution,
- Pursuing a sustainable policy of controlled waste generation,
- Reducing the adverse impacts of industry on operating environment,
- Facilitating regulatory compliance with national laws and international manufacturing standards,
- More cost-efficient working conditions and heightened recognition of employee education, up-skilling/re-skilling and worker commitment.

The benefits resulting from Industry 5.0-consistent efforts are intrinsically linked to the nature of the solutions employed, encompassing:
- Reduced production costs achieved by curtailing energy consumption, which results from eliminating the need for lighting, air conditioning, heating, and other amenities essential for human work,
- Reduced physical and mental workloads through the judicious use of worker knowledge and skills based on their individual predispositions and qualifications,
- Minimized human-error-related accidents achieved by dispensing with direct human involvement in production tasks, either relegating human roles to oversight functions or scaling back engagement in favor of machine-driven processes, thereby mitigating risks and nuisances,
- Reducing the number of failures caused by the human workers by limiting human involvement in production work and increasing reliance on machines,
- Enhanced performance efficiency by employing automation-driven reduction in human involvement coupled with the optimization of work intensity aligned with human capabilities.

An enterprise that consistently adheres to the principles of Industry 5.0 stands to reap the benefits across every asset of its impact. In the efforts to align technology with human needs, such an enterprise will:
- Deploy solutions that mitigates potential network overloads and facilitates the sharing of critical data,
- Develop solutions for production monitoring and scenario prediction (e.g. as embodied in the form of digital twins),
- Offer virtual tutorials for employees to preempt risks during task execution,
- Leverage artificial intelligence to empower robots and other machines to learn from human operators and apply acquired knowledge in task execution.

In light of the pivotal role of humans in ensuring the efficient operation of Industry 5.0, it is essential to identify the requirements for facilitating the transition from physical to cognitive work [5], the efficient performance of value-added production tasks, and the coexistence of humans alongside autonomous machines, such as collaborative robots. All of this requires the use of digital solutions geared towards enhancing production efficiency, a reassessment of the current human-centered approaches, and an alignment of technology and organization structures with worker needs. Automation, in this context, is envisaged as a means to augment the physical, sensory, and cognitive capabilities of human workers [29].

**SUMMARY AND CONCLUSIONS**

Industry 5.0 encapsulates three sets of requirements pertaining to humans, the organizational environment, and technology. Unlike Industry 4.0, Industry 5.0 mandates the integration of human perspectives into decision-making processes and the active involvement of human actors in task execution [25, 29]. Industry 5.0 also underscores the use of human creativity and resilience in the face of errors [1, 18]. It requires the cultivation of close symbiotic "relationships" between humans and machines, fostering the use of every developmental opportunity on the shop floor. This symbiosis yields tangible benefits for all parties involved, propelling Industry 5.0 into a global ecosystem that evolves through the improvement of existing solutions to shifting needs, with an ever-growing reliance on information technology.

The rise of Industry 5.0 requires a reassessment of industrial processes and the formulation of solutions tailored to the specific challenges inherent to various industries. The objective is to attain optimal results across all facets of operations, encompassing human engagement, organizational dynamics, and technological integration [23, 30, 31]. This strategic shift is an inevitable outcome of evolving production principles. The chosen solutions must not only empower workers across all operational domains. It is imperative that technical solutions coalesce with human collaborators, only supplanting human involvement where demonstrably justified by tangible benefits. The fulfilment of these requirements hinges on the recognition of constraints that affect operational efficiency. This objective should be pursued within the overarching context of Industry 5.0, which emphasizes resilience and societal value as key criteria, along with the essential considerations for setting deployment priorities.

Industry 5.0 ushers in an array of conditions, expectations, potential challenges, and disruptions. Foremost, businesses must acknowledge the following key tenets [31]:
- Standardization, a pivotal mechanism for averting significant technological pitfalls and aligning the expectations of both society and the economy,
- Fast and highly efficient production that may lead to significant overproduction,
- Older members of society and stakeholders, in particular, will grapple with significant challenges when confronted with the ongoing industrial revolution.

It is therefore crucial to:
- Consider the extent and the manner in which autonomous systems must adhere to ethical principles governing their function within a broader work and life environment,
− Ensure that ethical behavior in autonomous systems is subject to continuous verification and adaptation in response to evolving conditions,
− Develop solutions aimed at cultivating ethical behavior in autonomous systems.

Indeed, the operational environment of smart factories, underpinned by supervisory systems, demands meticulous attention to real-time interactions with human actors to optimize process efficiency. This requires anticipatory measures in response to emerging issues [9].

Leveraging the Internet of Services, organizations extend both internal and inter-organizational services, forging a value chain grounded in digital communication and collaboration systems. Technology should enable worker well-being within their working environments. Moreover, a systemic perspective and technological innovations should inform the resolution of issues spanning societal and individual realms. Notably, a persistent gap exists between the pace of technological advancement and societal evolution, on the one hand, and the shifting dynamics of the business landscape in many industries, characterized by ambiguous principles governing process implementation. A thorough understanding of these principles is essential for the effective execution of tasks in a new environment, achieved through extensive interaction with devices while recognizing the central role played by humans.

Industry 5.0 redefines the term "robot". Robots cease to be mere programmable automatons relegated to repetitive tasks. Instead, they evolve into human collaborators in the specific sphere of labor [6]. Collaborative robots that are aware of human presence during task execution, factor in safety and risk considerations. They transcend mere perception, exhibiting an understanding of human presence, as well as the goals and expectations of human operators [6, 16]. Handling these advanced robotic systems represents a daunting task for organizations. In the activities undertaken, it is vital to harness human flexibility in conjunction with the precision of machines and IT systems to ensure a friendly working environment [6, 18, 32].

A significant constraint on the applicability of Industry 5.0 lies in its associated costs. The challenge arises from the difficulty of quickly demonstrating a return on investment, which consequently deters securing the requisite funding. The long time it takes to realize tangible benefits further discourages investment [8, 33]. Nevertheless, the experience gleaned from the adoption of Industry 4.0 shows that the present course of action is well advised.

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