ISSN 2683-345X
journal homepage: http://ijiemjournal.uns.ac.rs/

International Journal of Industrial Engineering and Management

2024 / ARTICLE-IN-PRESS / 367

Original research article

On Job Profiles Enlargement and Enrichment when Lean and Industry 4.0 Paradigms Meet

C. Cimini[a,*] 0000-0001-8274-9821, A. Lagorio[a] 0000-0003-1489-0625,
D. Romero[b] 0000-0003-3610-0751, P. Gaiardelli[a] 0000-0002-2207-3628,
G. L. Tortorella[c] 0000-0003-2396-4665

[a] *University of Bergamo, Department of Management, Information and Production Engineering, Dalmine (BG), Italy;*
[b] *Tecnológico de Monterrey, Departments of Industrial Engineering and Mechatronics, Mexico City, Mexico;*
[c] *The University of Melbourne, Department of Mechanical Engineering, Melbourne, Australia*

ABSTRACT

Integrating Industry 4.0 technologies in Lean Manufacturing shop floors is reshaping job profiles, emphasising increased task variety and the demand for diverse skills among workers. The conventional perception of operators solely performing specialised tasks is transforming into one where they are viewed as flexible production resources capable of managing a spectrum of activities. The accompanying flexibility necessitates the enlargement and enrichment of skills and responsibilities undertaken by workers on "Digital Lean shop floors". This research delves into the evolving definitions of "Job Enrichment" and "Job Enlargement" as discerned by Lean Manufacturing and Industry 4.0 experts through a comprehensive Delphi study. The investigation of these concepts holds theoretical and practical significance, as they serve as pivotal techniques in the (re-)design of job profiles. Understanding their current meanings is crucial, given their potential to elevate the motivational levels of workers, enhance job satisfaction, and consequently improve work performance and productivity. This exploration is essential in pursuing socially sustainable factories in the (near-)future, aligning with the transformative goals of Industry 4.0, and emphasising the integral role played by Lean Manufacturing practices in shaping the workforce dynamics of tomorrow.

ARTICLE INFO

Article history:
Received February 13, 2024
Revised July 22, 2024
Accepted September 23, 2024
Published online October 17, 2024

Keywords:
Lean manufacturing;
Industry 4.0;
Workforce 4.0;
Job enlargement;
Job enrichment

*Corresponding author:
Chiara Cimini
chiara.cimini@unibg.it

1. Introduction

The latest innovations brought by the *Industry 4.0 paradigm* into manufacturing [1] are affecting the job profiles of workers in terms of task variety and required skills [2]. Hence, workers are facing increasing "Job Enlargement" and "Job Enrichment" requirements to perform new and different activities and functions [3] on the emerging *Digital Lean shop floors* [4]. It has been observed that the increasing adoption of *Industry 4.0 technologies* has led to rethinking the role of the operator on the new Digital Lean shop floors [4], who is no longer seen as a performer of specialised tasks, but rather as a *flexible production resource* capable of managing different activities [5]. Moreover, such *flexibility* comes with the enlargement and enrichment of the skills needed and responsibilities to be accepted by a worker to perform a wider variety of activities and functions on a *Digital Lean shop floor* [3], [6].

Published by the University of Novi Sad, Faculty of Technical Sciences, Novi Sad, Serbia.

https://doi.org/10.24867/IJIEM-2024-4-367

Indeed, the growing adoption of digital and smart support systems suggests that the transformative impacts of the *Industry 4.0 paradigm* are poised to bring about favourable changes for the workforce, also in the light of the evolving scenarios towards *Industry 5.0*, which claims an increasing development of human-centric and socially sustainable systems [7]. The decline in physically demanding or repetitive tasks is expected, replaced by a rise in job roles demanding adaptability, problem-solving, and customisation skills [8]. Also, employees throughout the value chain will experience a fundamental transformation in how they engage with their work environment and job responsibilities. The heightened connectivity facilitated by IoT devices and intelligent workflows will empower individuals with tools that enhance the intelligence and agility of their work and its seamless integration and interconnectedness within the broader company, plant, or value chain. In light of this transformation, the discussions about the impacts of Industry 4.0 technologies on *job profiles* have started in the literature and are still running [9], [10].

In a context where the enlargement and enrichment of skills emerge as fundamental elements to face the new challenges that the implementation of Industry 4.0 technologies requires, *Lean Manufacturing*, understood as a learning system oriented towards a culture of improvement through the continuous transformation of organisational processes and skills, assumes a significant role [11]. Simultaneously, the innovation brought about by the implementation of *Industry 4.0 technologies* modifies how *Lean Manufacturing* is applied (i.e., *Digital Lean Manufacturing* [1]), thus raising the question of whether job enrichment and enlargement principles traditionally linked to the "Lean model" are still valid. These considerations led to the definition of the main research question of this research: *"How have job enrichment and job enlargement concepts been evolving, and are they currently defined?"*

Consequently, this research work aims to answer this question by exploring how "job enrichment" and "job enlargement" concepts have evolved and are currently being defined by Lean Manufacturing and Industry 4.0 experts through a Delphi study. Understanding their present meaning is of "theoretical" and "practical" relevance since both concepts represent important techniques for job profiles (re-)design that can be used to increase the motivational level of workers and job satisfaction, and therefore, work performance and productivity [12], which is essential for achieving *Socially Sustainable Factories of the Future* [13].

2. Background and Motivation

Lean principles have been ingrained in our factories for several decades, originating with Japan's Toyota Production System development around the 1980s. This system introduced techniques such as SMED, Jidoka, Just-in-Time, and key concepts like Muda (waste), Mura (unevenness), and Muri (overburden) [14]. The primary goal of *Lean Manufacturing* is to maximise customer value while minimising resource utilisation, encompassing costs and time without compromising quality or worker safety [13]. This objective is achieved through sub-objectives like reducing production times, eliminating waste, and lowering total costs [15]. In contrast, *Industry 4.0* is a relatively new concept centred on digitisation and automation, incorporating many technologies ranging from the Internet of Things (IoT) to Cloud Computing, Artificial Intelligence (AI), Advanced Robotics, Extended Reality (XR), and Cyber-Physical Systems (CPSs) [16]. It often refers to the networking of machines and processes to create smart factories, and its key strategic objectives include enhancing productivity, improving customer experience, reducing uncertainty, and achieving supply chain integration [17].

"Lean Manufacturing" and "Industry 4.0" aim to enhance efficiency, quality, and productivity but differ in their approaches. *Lean Manufacturing* relies heavily on employee mindset and involvement, viewing them as fundamental resources to promote change. In contrast, *Industry 4.0* appears more focused on machines and digitalisation, with concerns about the impact on employees and their potential "job displacement". Since the *Lean philosophy* emphasises training, involvement, and continuous employee feedback, recognising that employee mindset is critical for successful implementation, *Job Enlargement* and *Job Enrichment techniques* have been employed to increase flexibility and motivation, advocating for multi-skilling abilities in the workforce [18].

In Industry 4.0, "Job Enlargement" and "Job Enrichment" take on different roles. They result in the necessary consequences of introducing new digital and smart technologies and autonomous machines because roles diversify, as operators are freed from fixed tasks on single machines, enabling them to focus on addressing issues across different machines. Workers take on more *cognitive roles* as repetitive tasks are automated. Higher-level education and skills become crucial, with jobs requiring problem-solving abilities and transversal skills less susceptible to au-

tomation [8]. *Industry 4.0* encourages "Job Enlargement" and "Job Enrichment", but its rationale differs significantly from that of *Lean Manufacturing* [1].

A *structured theoretical framework* presented in [19] provides evidence about the specific features of *Lean Manufacturing* and *Industry 4.0* that affect the *Job Enrichment* and *Job Enlargement* dimensions, finally identifying reinforcement loops recognising the *Lean Philosophy* supporting the workers' involvement and learning attitudes while *Industry 4.0* enhancing tasks variability and flexibility to achieve increased productivity.

Given these premises, gaining insights into the development of *Job Enlargement* and *Job Enrichment concepts* through the perspectives of "Lean Manufacturing" and "Industry 4.0" becomes crucial, especially because these two paradigms coexist and are intertwined in today's manufacturing environments. This understanding holds significant importance for manufacturing stakeholders tasked with redesigning job profiles. Moreover, it is instrumental for higher education and vocational training entities that establish and consistently update learning paths and training courses. Therefore, a reshaped definition of the two concepts could be helpful to point out the main characteristics that must be accounted for when employing work design strategies in a digitalised and lean manufacturing context to maximise their impact in terms of business outcomes as well as workforce satisfaction and well-being.

3. Research Methodology

To answer the previously defined Research Question (RQ), the *Delphi method* has been selected. This approach is commonly employed to explore and understand the factors that impact decision-making on a specific issue, topic, or problem area [20]. It is particularly useful when a single opinion may be incorrect, misinformed, or biased towards a narrow perspective [21]. A *Delphi study* is a systematic and iterative process used to obtain a consensus view from a panel of experts [22]. The *Delphi approach* involves a representative group of experts to generate a more accurate and informed response than an individual's input. Unlike brainstorming or other group approaches, the *Delphi method* avoids direct interactions among individuals to prevent biased responses [23].

Additionally, the *Delphi method* helps minimise the influence of dominant individuals and aims to develop a consensus among experts on subjective matters [21]. It is worth noting that the *Delphi approach* also acknowledges and reports divergent opinions when complete consensus is not achieved [23]. Furthermore, it is essential to note that the *Delphi method* should not be mistaken for conventional questionnaire-based statistical sampling techniques [24]. In the *Delphi method*, panellists are selected based on their experience and knowledge of the topic under investigation rather than following statistical representativeness sampling rules [21].

The research guidelines provided by [21] have been used and are summarised in Fig. 1.

In the first step of the methodology, a *literature review* was conducted on the concepts of "Job Enrichment" and "Job Enlargement" and how they have evolved. The detailed literature review method and results are reported in a previously published research work [3]. This step had the objective of identifying the main dimensions of "Job Enrichment" and "Job Enlargement" to be further evaluated and mapping the evolution of the concepts' definitions through the last decades. This analysis showed that the two main production paradigms that have profoundly transformed the manufacturing context (i.e.,

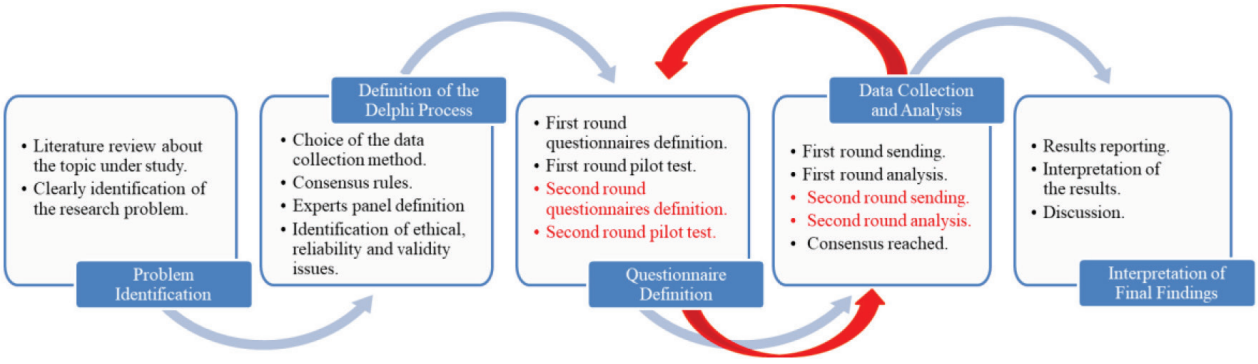

Figure 1. The Delphi Methodology

"Lean Manufacturing" & "Industry 4.0") have also influenced the nature of *Job Enrichment* and *Job Enlargement*. Therefore, the main research question presented in this work is: *How have the Lean Manufacturing and Industry 4.0 production paradigms modified the definitions of Job Enrichment and Job Enlargement?*

In the second step, the execution process of the Delphi methodology was defined, specifically by choosing how to collect data (i.e., through a *questionnaire* administered via e-mail) and what rules to establish for consensus. Generally, several rules can be applied to determine when consensus is reached (and, therefore, when further process rounds are no longer necessary) based on the convergence of expert responses or the decrease in responses received in each round [23]. In our case, we opted to achieve 80% convergence in responses. Furthermore, in this methodology phase, the *expert panel* was selected. This selection is a delicate phase because the reliability and validity of the results depend on it. The Delphi method utilises experts with relevant experience and knowledge in the studied subject. Therefore, selecting the panel of experts requires careful consideration. Specifically, the panel should include individuals familiar with and knowledgeable about the specific problem domain being addressed while maintaining anonymity. Since this is not a survey methodology and there is no need to achieve statistical representativeness, having a large panel of experts is unnecessary to obtain reliable results [21]. Even if the majority of Delphi studies include at least 10 participants, in the literature it is possible to find studies in which consensus was reached involving small samples of 5 or 6 experts [25], [26]. Using small samples is considered suitable for ranking-type Delphi studies, which compared to other kinds of Delphi (such as Policy or Decision Delphi) involves only a limited number of selected experts to identify and rank targeted issues. As it occurs in this research, ranking-type Delphi is mainly used in business to guide future management actions or research agendas [27]. The data on the consulted experts are reported in Table 1. Finally, based on the expert panel, possible issues concerning the research's ethics, reliability, and validity were identified. In particular, to guarantee the validity of the research, we ensured the presence of a couple of experts for each of the three main domains of the study, i.e. Lean Manufacturing, Industry 4.0 and Work organization, with at least 10 years of experience in academia, grounding on the widely recognized effect of the "wisdom of crowds" to achieve good judgements when it is not possible to provide direct experimentations [28].

In the third phase of the methodology, the *questions* for the first round of questionnaire submissions were defined. The questions are simple, partly open-ended and partly multiple-choice. To understand how much time is required to complete the questionnaire and if the questions are understandable and do not generate bias, the questionnaire was tested with a pilot example by two colleagues of the authors who did not participate in the panel. Then, the *first questionnaire* was sent to the experts.

In the fourth phase, the responses to the first questionnaire are *analysed*, and accordingly, going back to the third phase, *new questions* for the *second questionnaire* were derived. Then, the *second questionnaire* and the report from the previous round were tested again before being sent to the experts.

After the second round of questionnaire submissions, *consensus* was reached. Therefore, the final phase of *reporting* and *interpreting the results* was carried out, including a discussion regarding the results obtained from the Delphi method compared to the results from the scientific literature.

3.1 Delphi Survey Process and Results

This section reports the results of the two Delphi study rounds.

Table 1. Background Details of Experts

Expert	Working Area	Experience (years)
Expert 1	Lean Manufacturing	19
Expert 2	Automation and Industry 4.0	18
Expert 3	Lean Manufacturing	13
Expert 4	Business Organisation	17
Expert 5	Automation and Industry 4.0	12
Expert 6	Business Organisation	21

3.1.1 First Round of Delphi Study

The *first survey* was divided into two sections, one concerning *Job Enlargement* and the other regarding *Job Enrichment*. The answers were presented in parallel since the two sections are made of the same questions, referring to one definition or the other. The first question was in open form and asked to define the terms "Job Enlargement" and "Job Enrichment".

Concerning *Job Enlargement* definitions, experts responded:

- *"Can be defined in two different ways: (i) as an increase in the number of tasks related to a job, and (ii) as an expansion in the scope of a job in terms of diversity of tasks".*
- *"Increased job task variety and responsibility".*
- *"Increased scope of work through extending the range of duties and responsibilities within the same role or position".*
- *"Refers to the reduction of the level of specialisation of the role".*
- *"Expansion of the facets that a job entails (a.k.a. the number of different things expected of the employee)".*
- *"The increase of the scope of a job by the number and variety of tasks assigned to an organisational position".*

What can be noticed from these definitions is the recurrence of the use of some words. "Scope" – about *job scope* – meaning the number of different tasks expected to be covered by a job profile, together with words such as "expansion" or "increase"; then, "variety" complemented by the word "task", indicating an increase in the diversity of tasks expected to be performed by a *job profile*; and "responsibilities", in the context of the increased importance of job tasks. What is clear from these definitions is that *Job Enlargement* impacts the role of a worker, expanding his/her *job scope* and increasing his/her *responsibilities* by increasing the number of tasks associated with his/her job profile.

Concerning *Job Enrichment* definitions, experts responded:

- *"To add tasks of different nature to the employee".*
- *"Being able to do your work more satisfactorily from the perspective of the worker and the company".*
- *"Job enrichment is a process characterised by adding dimensions to existing jobs to make them more motivating".*
- *"Job enrichment refers to how designing a role to increase satisfaction at work".*
- *"Similar to job enlargement but the main driver is motivation".*
- *"Is the level of autonomy and responsibility in the execution of a job".*

Again, it can be found that there is some everyday use of words across most definitions. The first one is "motivation", described as the final *aim* or *driver* of *Job Enrichment*, and the second one, similarly, is "satisfaction", which seems to be a driver of *Job Enlargement*. Both words refer to a state-of-mind of workers. The experts agree that *Job Enrichment* is more about creating more stimulating and challenging *job profiles*.

Aiming at leveraging the "job profile" of a worker, the following section of the survey allowed the participants to assign a score (from 1 to 4) to 13 different job dimensions extracted from the literature [3], evaluating their relevance in the definition of "Job Enlargement" and "Job Enrichment". The dimensions were divided into three sections: (i) organisational, (ii) human, and (iii) technological.

As depicted in Fig. 2, all the *job dimensions* obtained similar average scores when comparing "Job Enlargement" and "Job Enrichment", except for the first four dimensions: (i) task variety, (ii) task significance, (iii) degree of autonomy, and (iv) hierarchy. This result was expected since *Job Enrichment* is better described by an increase in a job profile's significance and autonomy, while *Job Enlargement* is more about an increase in the variety of tasks to be performed by a *job profile*. Regarding the fourth dimension – "hierarchy" – it should be noticed that according to the experts, it is the less relevant dimension but still relevant when associated with the *Job Enrichment* definitions.

Another observation that might be important to make is the fact that, on average, *human dimensions* (including satisfaction, motivation, educational level, problem-solving, and skills and competencies) are considered more relevant than *technological dimensions* (addressing technologies employed, and efficiency and quality obtained from their usage) (See Table 2).

Entering into the discussion of "Job Enrichment" and "Job Enlargement" in the contexts of *Lean Manufacturing* and *Industry 4.0 paradigms*, four experts think that the concept of *Job Enlargement* can have a different meaning when introduced in the *Industry*

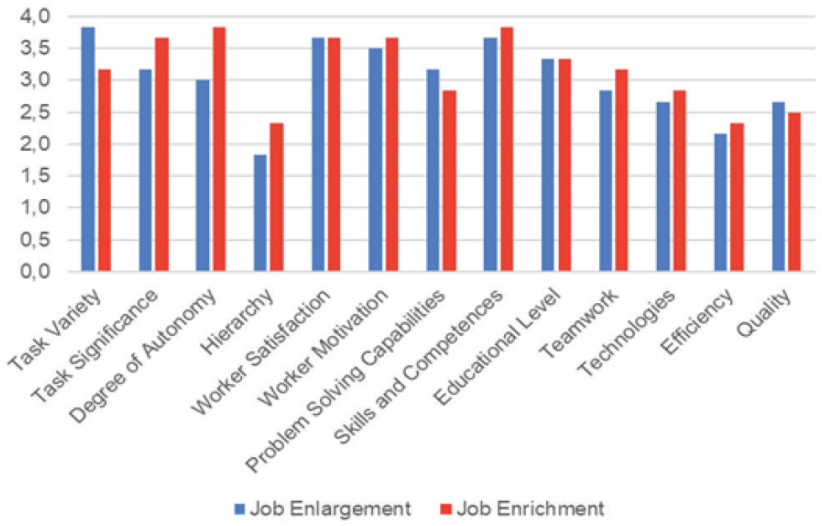

Figure 2. Average Scores that were given to the Dimension's Relevance in defining "Job Enlargement" and "Job Enrichment" Terms

Table 2. Average Scores of the Dimension's Relevance in Defining "Job Enlargement" and "Job Enrichment" Terms

Dimensions	Job Enlargement Average Score	Job Enrichment Average Score
Organisational	3,0	3,3
Task Variety	3,8	3,2
Task Significance	3,2	3,7
Degree of Autonomy	3,0	3,8
Hierarchy	1,8	2,3
Human	3,4	3,4
Worker Satisfaction	3,7	3,7
Worker Motivation	3,5	3,7
Problem-Solving Capabilities	3,2	2,8
Skills and Competences	3,7	3,8
Educational Level	3,3	3,3
Teamwork	2,8	3,2
Technological	2,5	2,6
Technologies	2,7	2,8
Efficiency	2,2	2,3
Quality	2,7	2,5

4.0 context. Experts said that *Industry 4.0* will reinforce and increase "Job Enlargement" by enhancing the importance of all the *technological dimensions*, the level of integration of business processes, and changes in the job functions and roles introduced by the Fourth Industrial Revolution. Only one expert thinks that "Job Enlargement" has a different meaning when introduced in a *Lean Manufacturing* context since it can be considered "a change in scope of functions and roles", affected by implementing *Lean practices*.

Furthermore, two out of six experts agree on identifying differences in the definition of "Job Enlargement" between the *Lean Manufacturing* and *Industry 4.0 contexts*. When asked why, one responded that *Lean Manufacturing* is more "human-centric", while *Industry 4.0* is "technology-centric"; the other expert responded that *Job Enlargement* is more "horizontal" in a *Lean Manufacturing context*, while in the *Industry 4.0 context*, it is more "vertical" growth.

Among the experts, two out of six think the "Job Enrichment" concept can have a different meaning when introduced in the *Industry 4.0 context*; when explaining why, both experts cited the presence of new technologies and tools that might create new

types of tasks for specific *job profiles*. Only one expert thinks the "Job Enrichment" concept can have a different meaning when introduced in the *Lean Manufacturing context*. When asked why, the expert stated that "Different workload balance may be found with standardisation of activities". Finally, when experts were asked if there are differences in the "Job Enrichment" definition in its *Lean Manufacturing* and *Industry 4.0 contexts*, all the experts stated that there are none.

3.1.2 Second Round of Delphi Study

After completing the analysis of the first-round survey, a *second-round survey* was designed and submitted to the same experts. The second round survey objectives were three: (OBJ1) Understanding which features of Industry 4.0 would most likely affect Job Enlargement and Job Enrichment concepts; (OBJ2) Understanding if Job Enlargement and Job Enrichment concepts are relevant in an Industry 4.0 context; and (OBJ3) Designing and validating a new definition for Job Enlargement and Job Enrichment, which also accounts for their new conceptualisations taking into account the Industry 4.0 context.

To reach the first objective, the question was: *How much will some features of Industry 4.0 modify the present Job Enlargement and Job Enrichment definitions?* The features taken under consideration, derived from the first round experts' answers, were: (i) new equipment like robots and autonomous machines, which will change how some jobs are performed and will presumably require new types of skills from the workers; (ii) business process(es) integration denoting "vertical" and "horizontal" integrations, inside and outside of the company; (iii) digitalisation referring to the internet of things, cloud computing, big data, and digital twins, and (iv) emergence of new roles which in a way is connected to the previous features, since new roles may emerge as a consequence of them.

Fig. 3 presents the average scores assigned by the experts to each *Industry 4.0 feature*. As can be depicted, "Job Enlargement" vs. "Job Enrichment" presents a significant difference in the scores assigned to "new equipment" and "business process integration", which the experts believe to have a more significant impact on *Job Enlargement* than on *Job Enrichment*.

Moreover, referring to the OBJ2, the results showcased in Fig. 3 do not reveal a clear winner between "Job Enlargement" vs. "Job Enrichment"; the implementation of the *Industry 4.0 paradigm* in a company might lead to a *vertical* (i.e., more autonomy and responsibility) or a *horizontal* (i.e., increased job-tasks variety) *job profile evolution*.

The last part of the survey concerned OBJ3, which addresses the development of new definitions for "Job Enlargement" and "Job Enrichment". First, all experts agreed that "general literature definitions of Job Enlargement and Job Enrichment are feasible in a Lean Manufacturing context", given that literature describes *Job Enlargement* as – an increase in job-tasks variety in a job profile, resulting in a "horizontal" job expansion, and *Job Enrichment* as – adding dimensions to existing roles in a job profile to increase motivation.

This result is in line with *Lean theory*, particularly with the concept of *polyvalence* (cf., a multi-task and multi-skilled worker) [29], where "horizontal" and "vertical" job evolution are considered an essential part of *Lean Manufacturing*, fully integrated into its context.

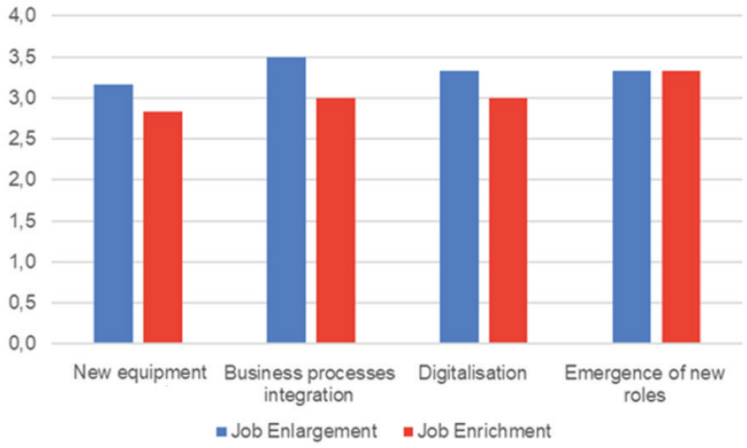

Figure 3. Average Scores assigned by the Experts when asked: How much would these Industry 4.0 features modify Job Enlargement and Job Enrichment definitions?

Second, the experts agreed on a – new definition – of *Job Enlargement* proposed in light of the Industry 4.0 paradigm: *"is the expansion of the scope of a job profile, through an increase in the variety of tasks assigned to it, also resulting in a limited increase of responsibility. In the context of Industry 4.0, it is usually a response to introduce new technologies that require mainly supervision and decision-making activities".*

The new definition expands the traditional concept of *Job Enlargement* with the new Industry 4.0 perspective. One expert suggested adding "new technologies and processes" to the definition instead of only "new technologies".

Finally, *Job Enrichment* was defined as *"a process that aims to increase worker satisfaction and motivation, not only through an enlargement in job scope but also by increasing the level of autonomy and responsibility in the execution of such job. In the context of Industry 4.0, Job Enrichment will be significant considering the shift of tasks assigned to the workers, from manual tasks with the responsibility to a higher level and more autonomous tasks".*

All experts but one agreed with the first part of the definition, which accounts for the traditional concept of *Job Enrichment*. The expert in disagreement deemed that *Job Enrichment's* main aim is to increase workers' satisfaction and motivation and reduce coordination efforts from an organisational perspective. Nevertheless, all experts agreed with the second part of the definition, which accounts for the new *Industry 4.0 context*, suggesting in one case adding examples of low-responsibility tasks (e.g., restocking a CNC centre) and higher-level tasks (e.g., troubleshooting a CNC centre).

4. Discussion

The evolving definition of *Job Enlargement* brings forth a multifaceted landscape with implications across education, research, industrial practices, and an inherent paradox. In *education*, the emphasis lies on cultivating supervisory and decision-making skills within the workforce. This shift demands operators to not only execute tasks but also to oversee and make informed decisions, marking a departure from traditional roles. These are aspects that are particularly stressed also by the main *Lean techniques* [14] and consequently, this result seems to confirm the importance of the relation between one of the principal characteristics of *Job Enlargement*, i.e., "flexibility", and the *Lean techniques* that acting on people and processes dimensions could help in improve it [19]. The *research dimension* of *Job Enlargement* involves the dynamic allocation of tasks between humans and machines. This aspect necessitates the development of decision-support tools, systems that enhance operator learning (such as explainable-based AI), and the creation of assistance/guidance systems, such as chatbots. The idea of the technology that could assist the workforce to support it in achieving the main productivity and efficiency goals is also one of the main topics faced by Industry 4.0 studies [14], [15]. On an *industrial scale*, there is a need to re-evaluate job descriptions and effectively manage mixed human-robot/machine teams. However, the *inherent paradox* emerges when considering the risk of overly guided systems. While increased efficiency may result from highly structured tasks, there is a danger of losing the capacity for innovative problem-solving and falling into a cognitive "repetitive movement" akin to Chaplin's assembly line effect. The challenge lies in finding a balance that leverages automation for efficiency while preserving the human touch necessary for creativity and problem-solving, preventing the potential pitfalls of a mechanised and monotonous work environment.

Also, the contemporary definition of *Job Enrichment* brings about a paradigm shift with significant implications in education, research, and industrial practices, all while introducing a nuanced paradox. In the *educational sphere*, a compelling need arises to structure training programs that foster autonomy and proactivity in students. Approaches such as project-based, theme-based, and problem-based learning become essential to cultivate the skills required for enriched roles, as advocated by [30]. In the *research domain*, integrating new technologies into *Job Enrichment* prompts a critical question: Can this approach enhance autonomy and responsibility for individuals with disabilities? In this context, *Job Enrichment* can contribute to increased inclusivity, affecting team dynamics, relationships with superiors, and broader societal integration. In fact, the development of *multiskilling abilities* also related to the so-called "soft skills" could help in the development of a more *inclusive work environment* [18]. On an *industrial scale*, the implications include flattening organisational structures and hierarchies, emphasising a shift towards goal-oriented work. However, a *nuanced paradox* emerges when contemplating the responsibility matrix in enriched roles. If a person is accountable for a process, but certain decisions within that process are made by machines, who bears the ultimate responsibility for the final choices? This

aspect raises questions about the impact on worker motivation and satisfaction. The *risk* of an unintended consequence, where increased responsibility may lead to decreased motivation if autonomy is compromised or to a higher level of stress, underscores the delicate balance that must be struck in the pursuit of *Job Enrichment*, and it is precisely in such a situation that the development of *Digital Lean techniques* applied to processes involving the interaction between humans and different technologies could prove to be a winning solution.

5. Conclusions

The adoption of *Industry 4.0 technologies* and modern *Digital Lean Manufacturing practices* on the shop floors have led to changes in how factory work is organised and performed [18] and, therefore, in the *job profiles* of workers. "Job Enlargement" and "Job Enrichment" as *job profile (re-)design techniques* offer the opportunity to create new jobs and renew existing ones in such ways that these are challenging, interesting, and meaningful for the workers and ultimately boost work performance and productivity [10], [31], [32]. In particular, *Job Enlargement* allows designing jobs where workers' needs for diverse job tasks meet the interests of the factory of a multi-skilled "polyvalent" workforce and allows operators to feel less meaningful and less challenged with the introduction of new smart and digital technologies [12]. Therefore, this study outlined that its current definition needs to evolve further to not simply add extra related tasks to a job but new, non-related tasks that avoid the current work-related stress and promote the acquisition of new knowledge and the development of new skills.

Meanwhile, *Job Enrichment* lets workers gain a high degree of autonomy and responsibility in their job tasks, allowing them to experience feelings of achievement, growth, and recognition, contributing to the efficiency of organisational operations [10]. Therefore, in the case of *Job Enrichment*, its current definition should mention that with increased autonomy and responsibility at the job, new opportunities may open for the worker to get involved in higher rank tasks and responsibilities. However, this research acknowledges several limitations, including potential biases stemming from the composition of the expert panel and the lack of universal applicability of findings across diverse manufacturing contexts that may have affected the depth of exploration. These limitations could be overcome with future research studies such as the performance of longitudinal studies to track the sustainability of job design strategies, cross-cultural analyses to understand cultural variations, quantitative validation of qualitative findings, exploration of technological integration into job design practices, investigation of the impact of job design on worker well-being, and development of training programs to prepare the workforce for Industry 4.0 environments. Addressing these limitations and pursuing these research directions can further our understanding of job design in the context of Industry 4.0 and contribute to developing effective workforce strategies.

Funding

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

References

[1] D. Romero, P. Gaiardelli, D. Powell, T. Wuest, and M. Thürer, "Digital Lean Cyber-Physical Production Systems: The Emergence of Digital Lean Manufacturing and The Meaning of Digital Waste," in Advances in Production Management Systems, Production Management for Data-Driven, Intelligent, Collaborative, and Sustainable Manufacturing, I. Moon et al. (Eds.), IFIP AICT, Springer Cham, 2018, pp. 11–20, doi: 10.1007/978-3-319-99704-9_2.

[2] S. Fareri, G. Fantoni, F. Chiarello, E. Coli, and A. Binda, "Estimating Industry 4.0 Impact on Job Profiles and Skills using Text Mining," Computers in Industry, vol. 118, p. 103222, 2020, doi: 10.1016/j.compind.2020.103222.

[3] A. Lagorio, C. Cimini, and P. Gaiardelli, "Reshaping the Concepts of Job Enrichment and Job Enlargement: The Impacts of Lean and Industry 4.0," in Advances in Production Management Systems, Artificial Intelligence for Sustainable and Resilient Production Systems, A. Dolgui et al. (Eds.), in IFIP AICT, Springer Cham, 2021, pp. 721–729. doi: 10.1007/978-3-030-85874-2_79.

[4] D. Romero, M. Zanchi, P. Gaiardelli, D. J. Powell, and G. L. Tortorella, "Assembling Method-based Toolboxes for the Implementation of Industry 4.0 Technologies in the Digital Lean Manufacturing World," in 29th International ICE-Conference on Engineering, Technology and Innovation, 2023, pp. 1–7, doi: 10.1109/ ICE/ ITMC58018.2023.10332367.

[5] P. Fantini, M. Pinzone, and M. Taisch, "Placing the Operator at the Centre of Industry 4.0 Design: Modelling and Assessing Human Activities within Cyber-Physical Systems," Computers & Industrial Engineering, vol. 139, p. 105058, 2020, doi: 10.1016/j.cie.2018.01.025.

[6] E. Kaasinen et al., "Empowering and Engaging Industrial Workers with Operator 4.0 Solutions," Computers & Industrial Engineering, vol. 139, p. 105678, 2020, doi: 10.1016/j.cie.2019.01.052.

[7] S. Nahavandi, "Industry 5.0—A Human-Centric Solution," Sustainability, vol. 11, no. 16, p. 4371, 2019, doi: 10.3390/ su11164371.

[8] C. Cimini, D. Romero, R. Pinto, and S. Cavalieri, "Task Classification Framework and Job-Task Analysis Method for Understanding the Impact of Smart and Digital Technologies on the Operators 4.0 Job Profiles," Sustainability, vol. 15, no. 5, p. 3899, 2023, doi: 10.3390/su15053899.

[9] J. Pontes et al., "Relationship between Trends, Job Profiles, Skills and Training Programs in the Factory of the Future," in 22nd IEEE International Conference on Industrial Technology (ICIT), Valencia, Spain, IEEE Xplorer, 2021, pp. 1240–1245. doi: 10.1109/ICIT46573.2021.9453584.

[10] S. Waschull, J. A. C. Bokhorst, J. C. Wortmann, and E. Molleman, "The Redesign of Blue- and White-Collar Work Triggered by Digitalisation: Collar Matters," Computers & Industrial Engineering, vol. 165, p. 107910, 2022, doi: 10.1016/j.cie.2021.107910.

[11] M. Ballé, J. Chaize, and D. Jones, "Lean as a Learning System: What do Organizations need to do to get the Transformational Benefits from Toyota's Method?," Development and Learning in Organizations: An International Journal, vol. 33, no. 3, pp. 1–4, 2019, doi: 10.1108/DLO-11-2018-0147.

[12] N. E. Alias et al., "Managing Job Design: The Roles of Job Rotation, Job Enlargement and Job Enrichment on Job Satisfaction," Journal of Economic & Management Perspectives, vol. 12, no. 1, pp. 397–401, 2018.

[13] D. Romero, J. Stahre, and M. Taisch, "The Operator 4.0: Towards Socially Sustainable Factories of the Future," Computers & Industrial Engineering, vol. 139, p. 106128, 2020, doi: 10.1016/j.cie.2019.106128.

[14] M. A. Lewis, "Lean Production and Sustainable Competitive Advantage," International Journal of Operations & Production Management, vol. 20, no. 8, pp. 959–978, 2000, doi: 10.1108/01443570010332971.

[15] M. Alefari, K. Salonitis, and Y. Xu, "The Role of Leadership in Implementing Lean Manufacturing," Procedia CIRP, vol. 63, pp. 756–761, 2017, doi: 10.1016/j.procir.2017.03.169.

[16] L. D. Xu, E. L. Xu, and L. Li, "Industry 4.0: State of the Art and Future Trends," International Journal of Production Research, vol. 56, issue 8, pp. 2941–2962, 2018, doi: 10.1080/00207543.2018.1444806.

[17] B. Meindl, N. F. Ayala, J. Mendoca, A. G. Frank, "The Four Smarts of Industry 4.0: Evolution of Ten Years of Research and Future Perspectives," Technological Forecasting and Social Change, vol. 168, p. 120784, 2021, doi: 10.1016/j.techfore. 2021.120784.

[18] I. Alony and M. Jones, "Lean Supply Chains, JIT and Cellular Manufacturing – The Human Side," Issues in Informing Science and Information Technology, vol. 5, pp. 165–175, 2008, doi: 10.28945/1003.

[19] C. Cimini, A. Lagorio, and P. Gaiardelli, "The Evolution of Operators' Role in Production: How Lean Manufacturing and Industry 4.0 Affect Job Enlargement and Job Enrichment," International Journal of Production Research, vol. 61, no. 24, pp. 8493–8511, 2022, doi: 10.1080/00207543.2022.2152894.

[20] H. A. Linstone and M. Turoff, The Delphi Method. Reading, MA: Addison-Wesley, 1975.

[21] F. Hasson, S. Keeney, and H. McKenna, "Research Guidelines for the Delphi Survey Technique," Journal of Advanced Nursing, vol. 32, no. 4, pp. 1008–1015, 2000, doi: 10.1046/j.1365-2648.2000.t01-1-01567.x.

[22] J. Landeta, J. Barrutia, and A. Lertxundi, "Hybrid Delphi: A Methodology to Facilitate Contribution from Experts in Professional Contexts," Technological Forecasting and Social Change, vol. 78, no. 9, pp. 1629–1641, 2011, doi: 10.1016/j.techfore.2011.03.009.

[23] H. A. von der Gracht, "Consensus Measurement in Delphi Studies: Review and Implications for Future Quality Assurance," Technological Forecasting and Social Change, vol. 79, no. 8, pp. 1525–1536, 2012, doi: 10.1016/j.techfore.2012.04.013.

[24] S. Thangaratinam and C. W. Redman, "The Delphi Technique," The Obstetrician & Gynaecologist, vol. 7, no. 2, pp. 120–125, 2005, doi: 10.1576/toag.7.2.120.27071.

[25] R. B. Akins, H. Tolson, B. R. Cole, "Stability of Response Characteristics of a Delphi Panel: Application of Bootstrap Data Expansion," BMC Medical Research Methodology, vol. 5, no. 37, 2005, doi: 10.1186/1471-2288-5-37.

[26] G. J. Skulmoski, F. T. Hartman, J. Krahn, J., "The Delphi Method for Graduate Research," Journal of Information Technology Education: Research, vol. 6, pp. 1–21, 2007, doi: 10.28945/199

[27] G. Paré, A.-F. Cameron, P. Poba-Nzaou, M. Templier, "A Systematic Assessment of Rigor in Information Systems Ranking-Type Delphi Studies," Information & Management, vol. 50, pp. 207–217, 2013, doi: 10.1016/j.im.2013.03.003.

[28] A. F. Jorm, "Using the Delphi Expert Consensus Method in Mental Health Research," Australian & New Zealand Journal of Psychiatry, vol. 49, 887–897, 2015, doi: 10.1177/0004867415600891.

[29] T. Fujimoto, "Functions and Emergence of New Work Organizations at Toyota," in Work Teams: Past, Present and Future, M. M. Beyerlein (Ed.), in Social Indicators Research Series, vol. 6, Dordrecht: Springer Netherlands, 2000, pp. 289–307, doi: 10.1007/978-94-015-9492-9_19.

[30] R. Salvador et al., "Challenges and Opportunities for Problem-based Learning in Higher Education: Lessons from a Cross-Program Industry 4.0 Case," Industry and Higher Education, vol. 37, pp. 3–21, 2023, doi: 10.1177/09504222221100343.

[31] S. Saleem, "The Impact of Job Enrichment and Job Enlargement on Employees Satisfaction Keeping Employee Performance as Intervening Variable: A Correlational Study from Pakistan," Kuwait Chapter of Arabian Journal of Business and Management Review, vol. 1, no. 9, pp. 145–165, 2012.

[32] O. Salunkhe and Åsa Fasth Berglund, "Industry 4.0 Enabling Technologies for Increasing Operational Flexibility in Final Assembly," International Journal of Industrial Engineering and Management, vol. 13, no. 1, pp. 38–48, 2022, doi: 10.24867/IJIEM-2022-1-299.