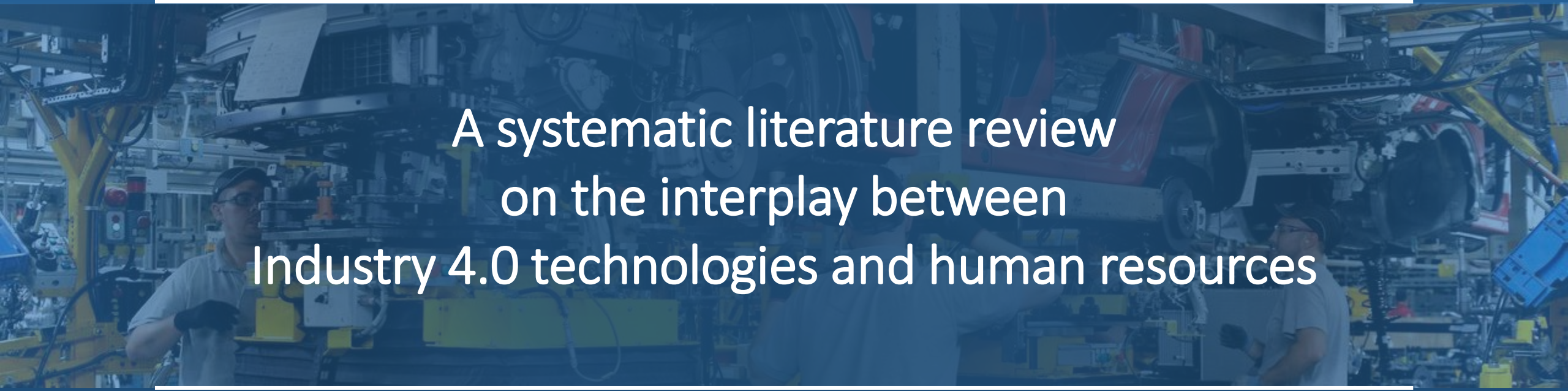
Babeş-Bolyai University

Faculty of Economics and Business Administration

27th International Conference on Production Research
Cluj-Napoca, 23-28.07.2023



A systematic literature review on the interplay between Industry 4.0 technologies and human resources

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Finanțat de Uniunea Europeană NextGenerationEU
Planul Național de Redresare și Reziliență

Introduction

Research question	**How does the interplay between I4.0 technologies and human resources influence the success of these technologies in the manufacturing industry?**
Theoretical relevance	Technological aspects of I4.0 are widely researched, while human resource implications received much less attention, even if their importance has been recognized by previous studies *(Neumann et al., 2021; Vereycken et al., 2021)*.
Practical relevance	The manufacturing industry faces a turning point caused by the fourth industrial revolution, but managing the digital transformation process is not possible without taking the human factor into consideration.
Data and methodology	Systematic literature review, 52 articles.

Agenda

1. Conceptual framework

2. Review approach

3. Literature results summary

4. Content analysis of the literature

5. Future research possibilities and research gaps identified

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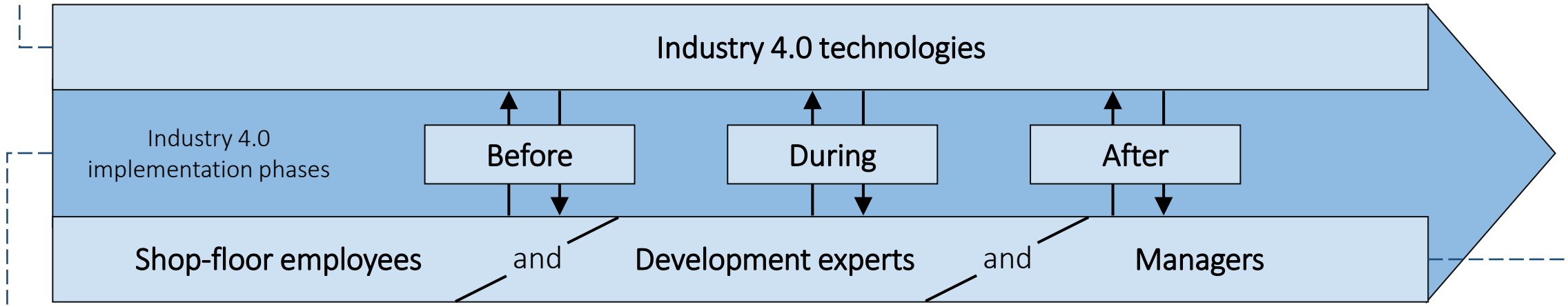
Conceptual framework development

The conceptual basis of our literature review focuses on the I4.0 concept and its bidirectional relationship with human resources in manufacturing firms.

Conceptual framework of the interplay between I4.0 and human resources

I4.0 is not just about automation and the use of advanced industrial robots; its distinctive feature is related to **interconnected, complex production systems**.



Some studies found idiosyncratic effects on human resources during **different implementation phases** *(Cardoso et al., 2012; Stornelli et al., 2021)*.

Shop floor employees, development experts and managers are all influenced by these novel technologies, and their role within the manufacturing firm might change as a result of implementing I4.0 technologies *(Schneider; 2018; Cagliano, 2019)*.

Source: own construction

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Inclusion criteria

To identify relevant literature, we have conducted a systematic literature review; following the recommendations of Durach et al. (2017). The search was conducted in the Clarivate Web of Science database on December 20, 2021.

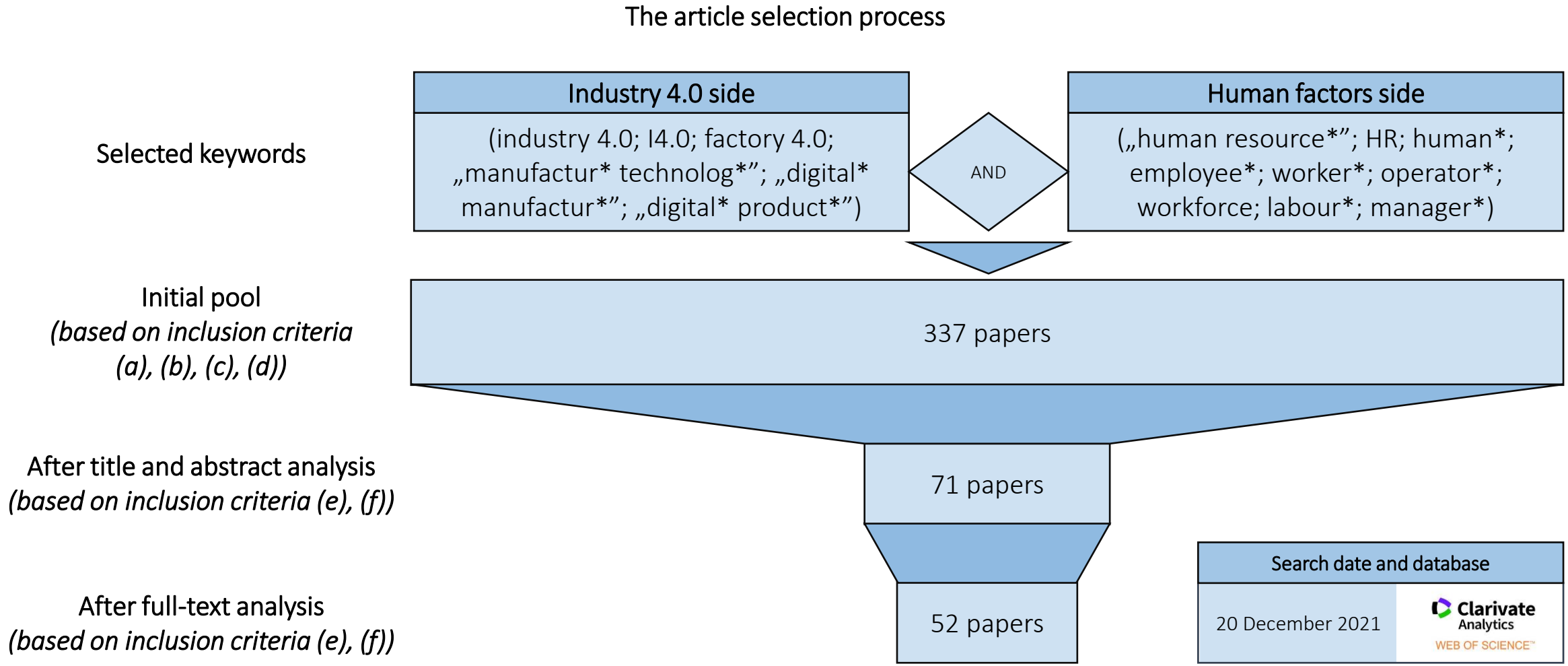
Inclusion criteria

Inclusion criteria	Detailed argument
(a) Papers written in English	English is the dominant research language in business and economics; the use of English ensures the accessibility and comparability of our results.
(b) Papers published in or after 2012	The concept of I4.0 appeared in 2012 *(Liao et al., 2017; Kagermann et al., 2013)*, the literature of the I4.0 only after this year enriched.
(c) Type of publication: scientific article, review or early access paper	We focus only on high scientific quality, peer-reviewed papers, where a rigorous review process ensures the reliability of the results. Other publication types, such as conference papers or book chapters were excluded.
(d) Based on its topic, the journal is included in Management, Business, Business Finance, Operations Research and Management Science, and/or Economics domains.	This review focuses exclusively on the managerial and economic implications of I4.0 technologies in the human resource management domain.
(e) The paper focuses on manufacturing industries	Some papers use the I4.0 concept in a non-manufacturing context, which have to be filtered out.
(f) The paper focuses on the interplay between HR and at least one type of I4.0 technologies	Topical restriction through search keywords to identify results relevant to our research question.

Source: own construction

The article selection process

Keywords were defined in relation with the two main domains of investigation, i.e., I4.0 and human resources. The keyword-based search resulted in a total of 337 articles. After the full-text analysis the final sample contained 52 articles.



Source: own construction

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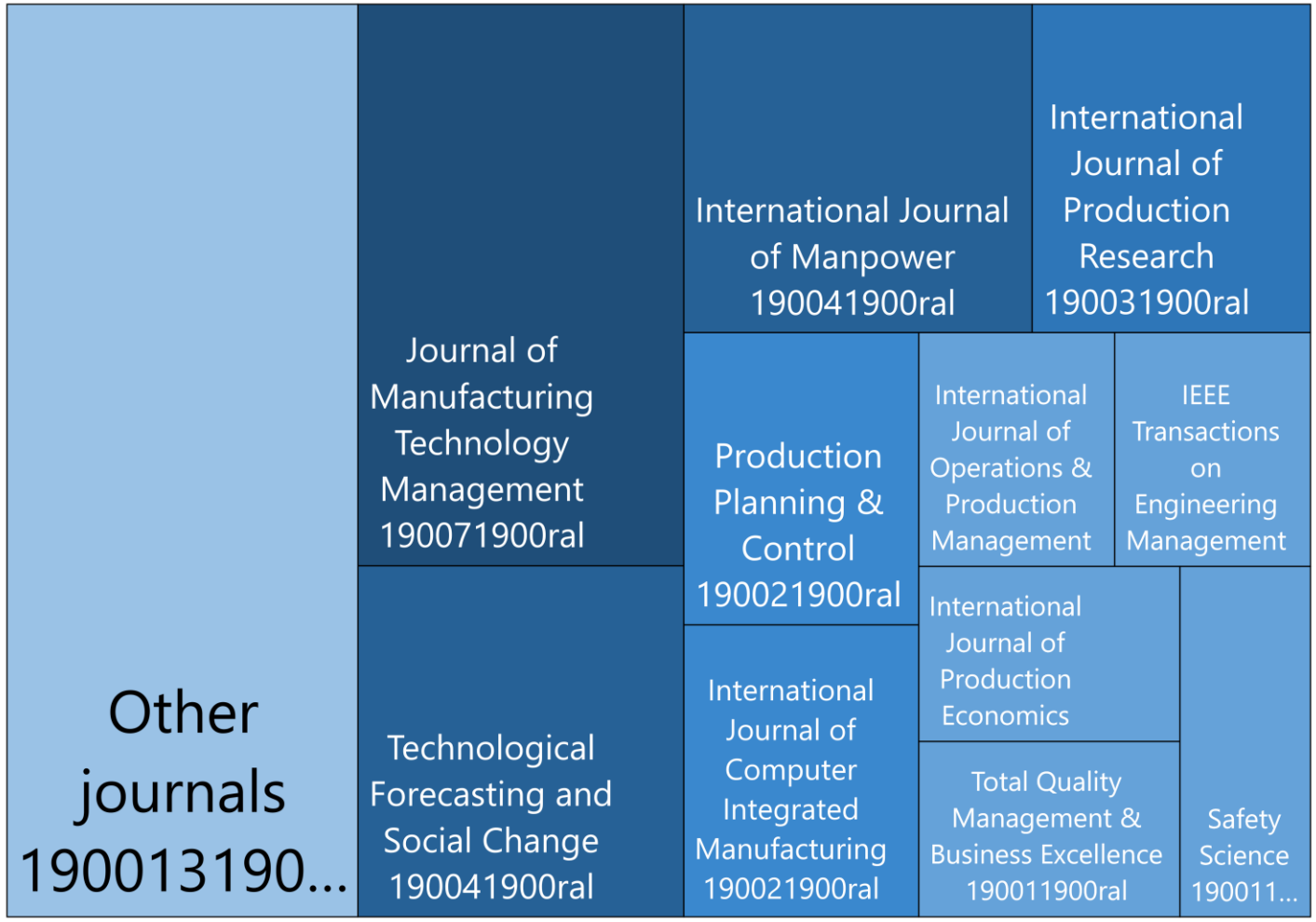
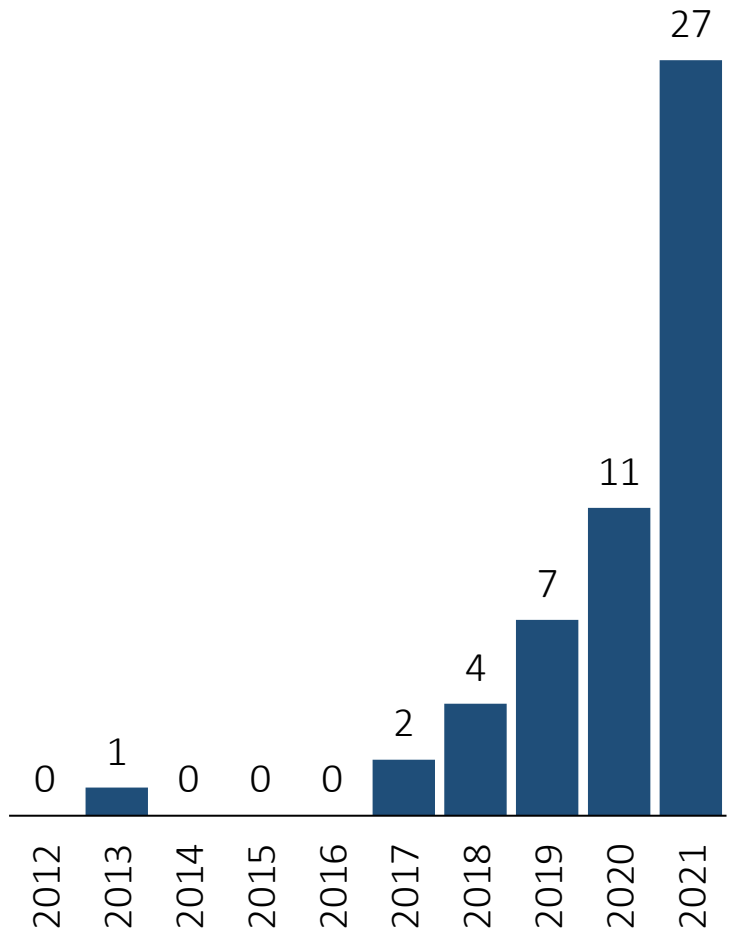
Journals and publication frequency

87 percent of the relevant papers are no older than five years, and that roughly 52 percent of the relevant publications in the sample were published in 2021.

Sample characteristics based on publication year and the publishing journals





Source: own construction based on the analyzed articles

The theoretical basis of articles

Out of the remaining 37 research papers, only 8 (outside of the 14 literature reviews and 1 conceptual paper) use an explicit theory. Some authors frame their research using a combination of two different theories.

2 articles:
technology acceptance model (TAM)
(Chatterjee at al., 2021; Cater et al., 2021)

TAM concept hypothesize that the use of the I4.0 technologies depends on the perceived ease of use and usefulness among the stakeholders of the company.

2 articles:
socio-technical systems (STS)
(Cagliano et al., 2019; Cimini at al., 2021)

STS approach claim that a company can be characterized by both technological and social variables and the co-design of the two factors is essential to establish an effective organization.

1 article:
resource-based view (RBV)
(Singh et al., 2021)

1 article:
contingency theory (CT)
(Nicolas-Agustin, 2021)

1 article:
human–technology–organisation (HTO)
(Cimini et al., 2021)

1 article:
technology-organization-environment (TOE)
(Chatterjee at al., 2021)

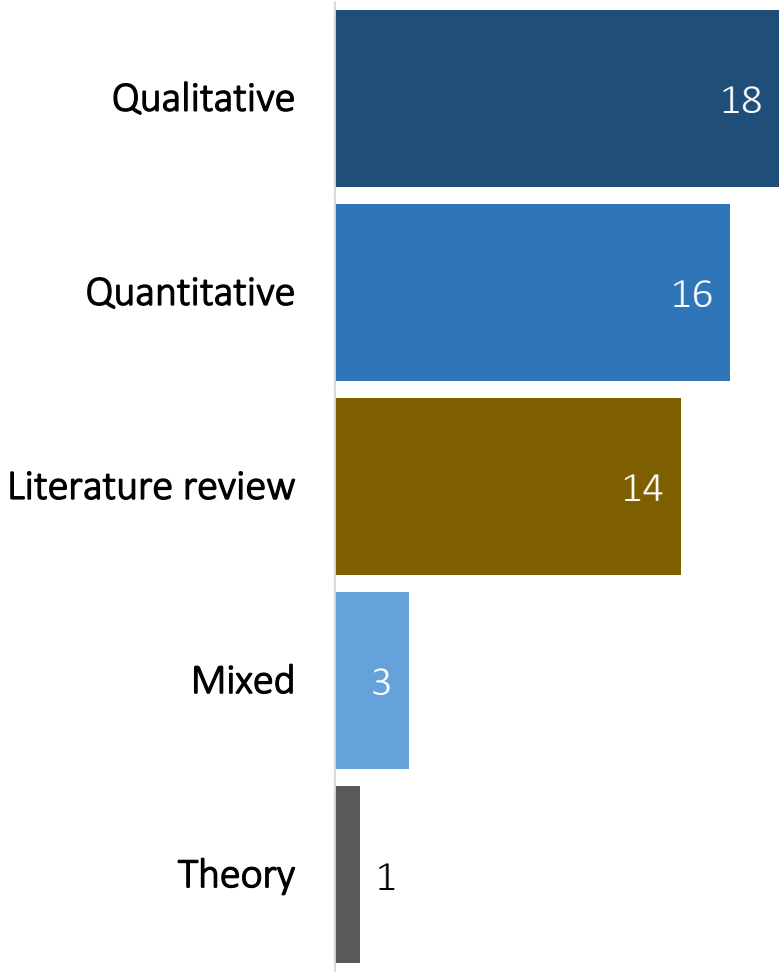
1 article:
career sustainability
(combined job demands-resources theory and conservation of resource theory)
(Chin et al., 2019)

1 article:
managerial controls
(Johansson et al., 2021)

Source: own construction based on the analyzed articles

Methods and research techniques

14 of the 52 articles are literature reviews. In 16 studies, quantitative methods are used, in 18, qualitative methods, in 3, mixed methodologies are used, and there is 1 conceptual paper.



Methods and research techniques

Case studies, interviews, and Delphi studies have traditionally served as the foundation for qualitative research. Many of these papers use the multiple case study approach, but Margherita and Braccini (2021) rely on a single case study.

Quantitative papers mainly use partial least squares structural equation modelling (PLS-SEM) and regression models as a research technique. In some articles fuzzy methods also appear.

The systematic review approach is typically used in literature review investigations. In some cases, the literature review is carried out with the intention of creating a conceptual framework for a particular I4.0 subject.

Articles using mixed methods combine both qualitative and quantitative techniques (e.g., interviews are used by Stentoft et al. (2021) to describe the results of the regression models).

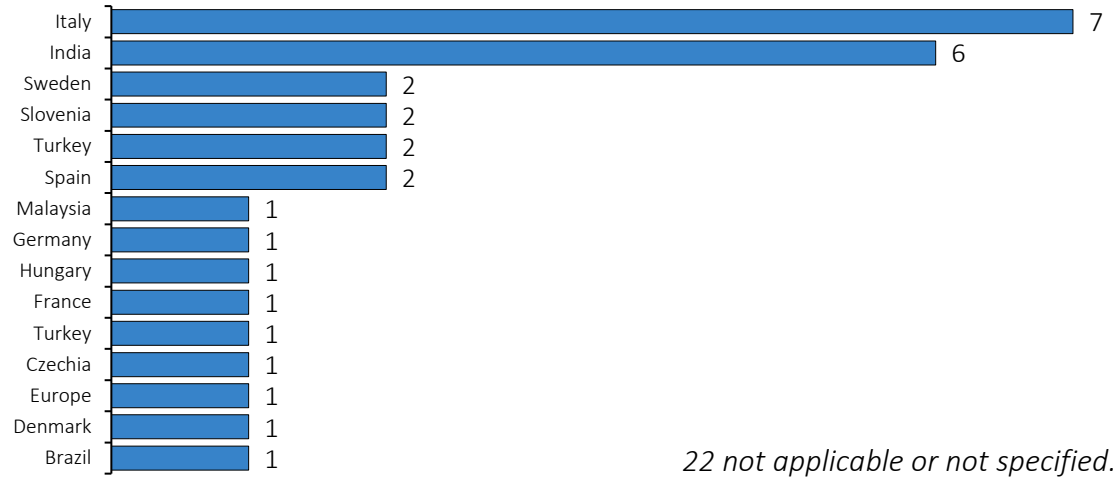
The sole publication that is a conceptual one (Golan et al., 2020) proposes a paradigm for operator-workstation interaction in an I4.0 environment by synthesizing earlier theories and findings.

Source: own construction based on the analyzed articles

Research samples

Most of the papers use a mixed industry sample. In terms of geographical focus, the majority of articles focus on single countries, such as Italy (7), India (6), Spain (2), Turkey (2), Slovenia (2) and Sweden (2) among others.

Geographical focus



22 not applicable or not specified.

Industrial focus

Sample size

Quantitative studies: most frequently use sample sizes between **100-300 companies/plants**.

Qualitative studies: the sample size mostly varies between **2 and 20 companies or plants**, but single case studies and papers based on more than 30 interviews are also published.

Literature review studies: **generally, about 50 papers** have been analysed, but there are some papers where the authors analysed more than 100 articles *(e.g., Niaki & Nonino, 2017; Blayone & VanOostveen, 2021)*. As a lower limit, Chin et al. (2019) and Badri et al. (2018) focus on niche themes analysing only 11 articles.

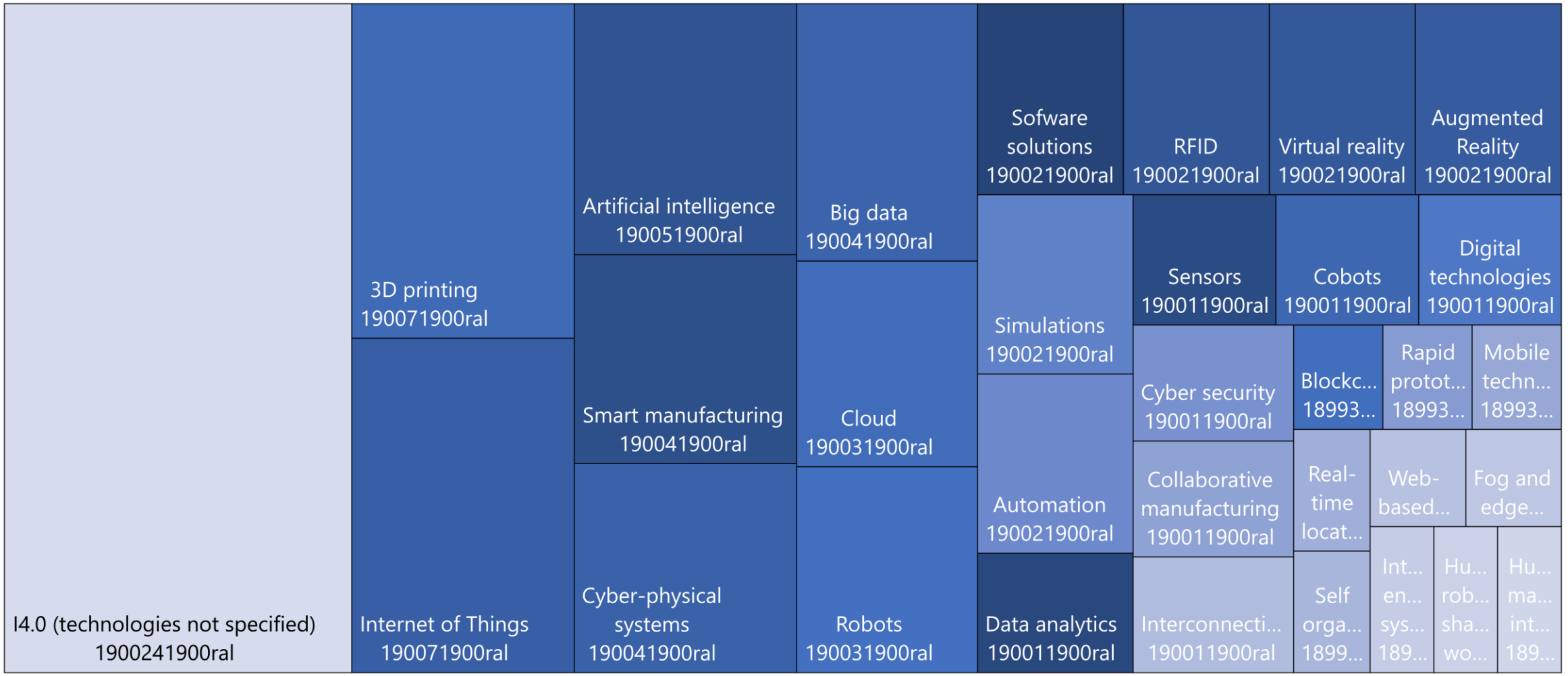
Mixed method studies: the average sample size of the **quantitative analysis around 100**, while the **qualitative research typically consists of a few case studies or some interviews**.

Source: own construction based on the analyzed articles

Thematic aspects covered

In our sample of articles 31 different technologies can be distinguished. It is also noticeable, that many articles do not specify the I4.0 technologies studied, using only the term “Industry 4.0” in a generic way.

I4.0 technologies included in the articles

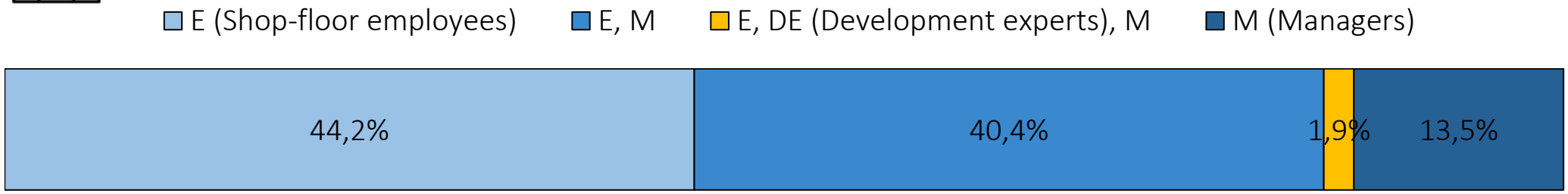


Source: own construction based on the analyzed articles

Thematic aspects covered

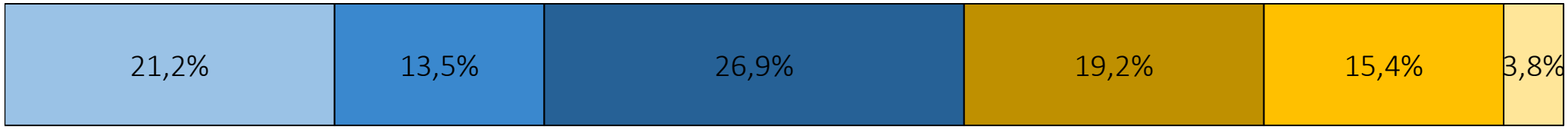
Most articles concerning the managerial level focus on the pre-implementation phase, while employee issues are mostly discussed in connection with the post-implementation phase.

The human resource categories covered



Employees play a defining role in the implementation of I4.0 technologies, thus it is not surprising that 85% of the articles reviewed include employee-related issues in their topics.

The I4.0 implementation phases covered



21.2% of the articles take only the “before” phase into consideration, another 13.5% focus exclusively on the implementation phase, while 26.9% highlight the “after” phase. Remaining articles cover more than one phase.

Source: own construction based on the analyzed articles

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The interplay between I4.0 technologies and managers

Current research mainly focuses on the “before” stage when investigating managerial questions. This is because management plays the most defining role in this phase, being the ones who make the decisions regarding the implementation of I4.0.

Main category	Before (B)	During (D)	After (A)
Support and leadership	Top-management support is crucial to promote the usefulness of I4.0 technologies.	Top-management support to the process of I4.0 implementation is a crucial factor.	
	Active support to develop a culture of learning, innovation and collaboration.	Managers should demonstrate the benefits of I4.0 technologies to the employees and address their concerns.	
	Different types of management controls (action, personnel, result, and cultural control) should be used together.	Strengthen organizational culture supporting I4.	
		Govern organizational and cultural change, taking into account potential acceptance problems and inertia tendencies	
		Managers should take into consideration that employees have different cognitive attitudes towards I4.0 technologies.	
		Different types of management controls (action, personnel, result, and cultural control) should be used together.	
Competences, know-how, experience	(Lack of) previous managerial experience and know-how influence the adoption of I4.0 solutions.	People-related managerial competences are necessary during the adoption of I4.0 technologies (e.g., entrepreneurial intelligence, agility, disruptive leadership, collaborative mindset).	
	Managers should have multidisciplinary knowledge	Managers should have multidisciplinary knowledge.	
	Managerial should develop awareness of the technical, managerial, and organizational aspects of the I4.0 solution.	Managerial awareness of the technical, managerial, and organizational aspects is vital for the successful implementation of I4.0.	
	Management skills and knowledge to handle digital management systems	Management skills and knowledge to handle digital management systems.	
	Managers should understand the production process and the interdependencies induced by I4.0 technologies (e.g., digital connectivity, I4.0’s relation with the organization etc.).	Need to understand the path to digital transformation.	
Business model changes	Assess the changes in the business model that might be needed.	Understand business model changes due to I4.0 technology adoption.	
	Redesign supply chain management approaches.	Adapt the existing or develop a new (e.g., more collaborative) business model around the I4.0 solution.	
		The whole factory should be reorganized to fully exploit I4.0 technologies.	
Strategy	Define a strategic and investment plan to implement I4.0	The implementation of I4.0 technologies needs change management activities to redefine organizational structures.	
	I4.0 implementation requires a strategic understanding and vision.	Communication and transparency regarding the objectives of I4.0 implementation	
	Develop a strategic transformation path, followed by an implementation plan.		
Managerial practices	Develop a communication plan to inform all employees, especially the ones unfamiliar with the new technology	The use of digital HR practices (e.g., work environment, reward system, teleworking, employee involvement) supports digital transformation.	
	Define digital training plans for employees.	Short hierarchical lines (operational presence of managers) can reduce the I4.0 implementation risks.	
	Technology selection in terms of effectiveness and requirements.	Direct employee trainings towards developing IT skills and human-machine interaction know-how.	
	Evaluate the impact on workers and design the future workplace.	Facilitate communication and collaboration between stakeholders.	
	Involve workers in the technology selection decision.	Involve workers in the implementation process.	
Resistance	Mid-level managers’ resistance.	Mid-level managers’ resistance.	
External support	External audits can help in evaluating the companies’ readiness to I4.0 implementation (current machines, processes, competencies etc.).	External experts (consultants and/or academicians) can help in securing the needed competencies (e.g., by trainings).	
	Securing support from government can help in mitigating the lack of skilled workforce.	Collaboration with external sources of knowledge in the process of digital transformation.	
HR challenges	Building up digital capabilities at firm level can be a challenge.	Need to find qualified personnel and organize personnel trainings.	
	Need to find qualified personnel and organize personnel trainings.	Lack of workers with a vision and commitment to I4.0 implementation.	
	Managing employee resistance and conflicting interests within the organization.	Need to relocate people to other areas, professional profile changes and organizational changes.	
		Managing employee resistance and conflicting interests within the organization.	

The existing research does little to address the effect of I4.0 on managers in the after the implementation phase.

own construction based on the analyzed literature

The interplay between I4.0 technologies and development experts

Developments experts are a rarely discussed group; most academics only pay attention to managerial and/or shop-floor employee levels.

Main category	Before (B)	During (D)	After (A)
Development	External experts can help fin the planning and design phase.		
	Internal development experts (e.g., subject matter experts) are crucial in the planning phase, since they know the relevant production technologies.		
Expertise	External experts could bring valuable knowledge, for example special technical knowledge even in the planning process.	People with deep I4.0 knowledge can accelerate the technology adoption.	
Change	[illegible] technological change.	Development experts (often from the lean personnel) can exploit the potentials from the new technologies.	
Knowledge management	External knowledge (e.g., from external experts, technology providers etc.) could be necessary.	Knowledge and information sharing between divisions is crucial.	After the implementation the knowledge sharing between the different plants should be a priority in order to avoid the same mistakes.
	Division-vide knowledge management also should be necessary in order to collect all the special know-how from the internal and external experts too.		The accumulated knowledge from the implementation should be standardized.

Developments experts are a rarely discussed group in literature.

own construction based on the analyzed literature

The interplay between I4.0 technologies and employees

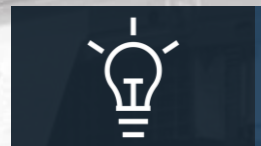
Discussions related to the changing I4.0 skills and competences focus primarily on the before and after-implementation stage.

Main category	Before (B)	During (D)	After (A)
Skills, competences	Highly skilled staff is a critical decision driver to implement I4.0.	Mix of young teams with adaptation capabilities supported by senior teams with more technical competences beneficial for I4.0 implementation.	The workforce performs more knowledge-intensive tasks with higher value added.
	Employees' qualification and willingness to work with new technologies should be in place before starting I4.0 implementation.		Knowledge and skills change quickly.
	Having the willingness, competences and motivation is needed for I4.0 readiness.		Next to technical knowledge, soft competencies (e.g., teamwork, decision making, problem solving, communication) also become important.
	Hiring new, qualified workforce is necessary.		Hiring new, qualified workforce could be necessary.
Trainings	Continuous learning, on-the-job trainings could be necessary to retain employees.	Continuous learning, on-the-job trainings could be necessary to retain employees.	Continuous learning and on-the-job trainings are necessary.
	Further education is needed to overcome the existing lack of skills.	Regular training of employees favours I4.0 implementation.	Lifelong learning path for shop-floor employees.
	Employee training is needed to embark on I4.0 adoption.		I4.0 technologies (e.g., VR/AR) can help in training employees and increase their effectiveness.
Job characteristics		Increased interaction between workers and machines can result unforeseen risks.	Employees' participation in self-managed teams and job autonomy will be higher.
			Increased interaction between workers and machines can result in unforeseen risks.
			New jobs are created, current jobs are changed.
			Network-type instead of hierarchical communication within all jobs.
			New job profile: higher job breadth, complexity, employee involvement and autonomy level, with increased cognitive demand.
			Enriched tasks for the workforce, participation in the continuous improvement of I4.0 technologies.
Behaviour	High perceived usefulness and the perceived ease of use positively influence the intention to use I4.0.	Innovative work behavior positively influences the digital transformation.	Negative impacts on the employee's psychological well-being.
	Employee resistance can be a barrier: changing attitudes and learning new technologies can be highly uncomfortable.	Employee resistance can be a barrier: changing attitudes and learning new technologies can be highly uncomfortable.	Increased expectations can lead to work overload and technostress.
	Employees' mental and social needs should be taken into consideration for implementing I4.0 technologies.	Employees' mental and social needs should be taken into consideration for implementing I4.0 technologies.	
		More frequent communication between employees helps I4.0 implementation.	
Replacement, reallocation	4.0 as a way to address labor shortage, replacing human work with machines.	Workers need to be reallocated to exploit I4.0 technologies.	Career sustainability in the digital manufacturing era requires resourcefulness, flexibility, renewability and the integration of knowledge sources.
	Fear of layoff can appear.		Decreasing human roles in automated factories.
			Higher job risk and insecurity.
			Some repetitive and manual jobs will be replaced.
Performance			I4.0 technologies can increase employee productivity.
			Safety level can increase, while the number of errors can decrease under I4.0.
			Employee involvement can enhance the impact of I4.0 technologies on operational performance.

Less results about the role of shop-floor employees during the implementation.

own construction based on the analyzed literature

Agenda



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Future research possibilities

According to the papers reviewed, future research possibilities are wide. Collecting the future research recommendations of the papers in our sample, many topics emerge.

- Country context *(Stentoft et al., 2021; Mishra & Venkatesan, 2021; Ozkan-Ozen & Kazancoglu, 2021; Liboni et al., 2019; Agostini & Filippini, 2019; Horváth & Szabó, 2019; Cugno et al., 2021; Cater et al., 2021; Mittal et al., 2020)*;
- differences between industries *(Stentoft et al., 2021; Ozkan-Ozen & Kazancoglu, 2021; Kazancoglu & Ozkan-Ozen, 2018; Zangiacomi et al., 2020; Shin et al., 2019; Cater et al., 2021; Mittal et al., 2020)*;
- required new skills *(Shet & Pereira, 2021; Schneider, 2018; Liboni et al., 2019; Marnewick & Marnewick, 2020)*;
- in-depth insights, qualitative research *(Vereycken et al., 2021; Cirillo et al., 2021; Golan et al., 2020; Moeuf et al., 2020)*;
- data from employees *(Nicolas-Agustin et al., 2021; Jerman et al., 2020)*;
- longitudinal analysis *(Malik et al., 2021; Zangiacomi et al., 2020)*;
- using quantitative methods (e.g., structural equation modelling) to validate qualitative results *(Dwivedi et al., 2017; Karadayi-Usta, 2020; Ito et al., 2021)*;
- job creation effects, new jobs *(Niaki & Nonino, 2017; Liboni et al., 2019)*;
- company characteristics (e.g., size) *(Cimini et al., 2021)*;
- enabling factors of I4.0 *(Chatterjee et al., 2021)*;
- effects on business models *(Horváth & Szabó, 2019)*;
- occupational risks *(Badri et al., 2018)*;
- human and non-human relations *(Marnewick & Marnewick, 2020)*;
- effects before and after implementation *(Vereycken et al., 2021)*;
- environmental contexts *(Ukobitz, 2021)* and
- effects of the COVID-19 pandemic *(Ancillo et al., 2021).*

Source: own construction based on the analyzed articles

Research gaps identified

The thematic analysis of this stream of literature reveals additional future research directions, which are different from the suggested research avenues by the authors in the sample of articles.

- First, in terms of management-level implications, it is evident that **managers' responsibilities throughout the post-implementation period have been overlooked**.
  - **How continuing managerial support** or **specific leadership principles** will affect how I4.0 technologies are used and improved over time? There is no information in the literature about **how managers' competencies should change** to fit the I4.0 context.

- Second, in the **pre-implementation and during the implementation stages**, a similar gap can be found for the **effects on shop-floor employees**.
  - Future research could investigate **how and to what extent employees should be involved** in the preparation and implementation phases of a new technology to facilitate a successful transition towards digital manufacturing.

- Third, current research orientations are very **fragmented and focused on specific areas** of the overall technology implementation landscape.
  - Future studies could incorporate these findings and provide more comprehensive empirical evidence on **how the various implementation stages should be managed** at the **different organizational levels**.

- Finally, the role of **development experts almost completely misses** from the literature.
  - Only a very few articles identified they and none of them examined **the effect of I4.0 on them and their effect on the I4.0 projects**.

Source: own construction based on the analyzed articles

Funding

This work was supported by the project entitled

"Strengthening the digitalization of businesses in Eastern Europe – a micro and macro-level approach"

funded by the **European Union – NextGenerationEU** project and the **Romanian Government**,

under the National Recovery and Resilience Plan for Romania,

contract no. 760036/23.05.2023, cod PNRR-C9-I8-CF 198/28.11.2022,

through the Romanian Ministry of Research, Innovation and Digitalization, within Component 9, Investment I8.

Thank you for your attention!

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Appendix

Summary of the relevant literature

Nr.	Author(s), year	Type of study	HR perspective	Type of human resources	I4.0 technology type(s)	Implementation phase(s)
1	Agarwal et al., 2021	QUAL	Employee skills, recruiting	E	I4.0 and automation	B, D, A
2	Agostini & Filippini,2019	QUAN	Employee skills	E, M	Various technologies	B
3	Ancillo et al., 2021	QUAL	Employee skills and qualification	E, M	Not specified	D
4	Badri et al., 2018	LR	Occupational health and safety	E	Various technologies	D, A
5	Bajic et al., 2021	LR	Managerial challenges	M	Various technologies	D
6	Blayone & VanOostveen, 2021	LR	Worker's readiness, competences	E	Not specified	B
7	Cagliano et al., 2019	QUAL	Job characteristics (job breadth, control and autonomy, cognitive demand, social interaction)	E, M	SM	D, A
8	Calabrese et al., 2021	QUAL	Reorganization, reallocation of employees	E, M	Various technologies	D, A
9	Cater et al., 2021	QUAN	Employee competences	E	Not specified	B
10	Chatterjee et al., 2021	QUAN	Competences (e.g., skills, knowledge, abilities); organizational factors (e.g., readiness, complexity)	E, M	AI	B
11	Chin et al., 2019	LR	Replacement of the operators at manufacturing companies	E	Not specified	A
12	Cimini et al., 2021	QUAL	Organisational change, competences	E	Not specified	A
13	Cirillo et al., 2021	QUAL	Employee skills	E	Various technologies	D, A
14	Costa & Portioli-Staudacher, 2021	QUAN	Worker flexibility enabled by I4.0	E	AR, HMI	A
15	Cugno et al., 2021	Mixed	Employee knowledge, competences and resistance	E	Various technologies	D, A
16	Da Silva et al., 2020	LR	Human capital as a barrier, managerial requirements	E, M	Various technologies	D
17	Dhalmahapatra et al., 2021	QUAN	Employee training	E	VR	A
18	Dwivedi et al., 2017	QUAN	Employee skills and resistance; management support	E, M	Additive manufacturing	B
19	Flores et al., 2020	LR	Employee activities, competences and skills	E, M	Various technologies	A
20	Golan et al., 2020	TH	Operator capabilities	E	OWI 4.0	A
21	Horváth & Szabó, 2019	QUAL	Employee skills, management skills	E, M	Not specified	B, D
22	Ito et al., 2021	QUAL	Employee resistance, managerial solutions	E, M	Not specified	B, D
23	Jerman et al., 2020	QUAL	Employee competences and job profiles	E	SM	A
24	Johansson et al., 2021	QUAL	Management practices; competences	M	Software solutions and sensors	B, D
25	Karadayi-Usta, 2020	QUAN	Employee skills and resistance	E, M	Not specified	B, D
26	Kauppi et al., 2013	QUAN	Absorptive capacity	E, M	E-purchasing	A
27	Kazancoglu & Ozkan-Ozen, 2018	QUAN	Personnel selection, competences, qualifications	E	Various technologies	B
28	Liboni et al, 2019	LR	Employment, job profile, qualification and skill requirements	E, M	Not specified	D, A
29	Malik et al., 2021	QUAL	Employee competences and technostress	E	AI	A
30	Margherita & Braccini, 2021	QUAL	Employee's welfare	E, M	Various technologies	D, A
31	Marnewick & Marnewick, 2020	LR	Employee competences	E	Not specified	A
32	Mishra & Venkatesan, 2021	QUAN	HR administration	E	Blockchain	B
33	Mittal et al., 2020	QUAL	Employee skills and education, managements vision	E, M	SM	B, D
34	Moeuf et al., 2020	QUAL	Managerial challenges	M	Not specified	B, D
35	Mohelska & Sokolova,2018	QUAN	Organizational culture, management	M	Not specified	D
36	Neumann et al., 2021	LR	Human roles under I4.0 (human-system interaction; employees' psychosocial needs)	E, M	Various technologies	B, D
37	Niaki & Nonino, 2017	LR	Management implications (e.g., technology selection, strategic challenges)	M	Additive manufacturing	B, D
38	Nicolas-Agustin et al., 2021	QUAN	HRM practices, work behaviour	E	Digital technologies	D
39	Osterrieder et al., 2020	LR	Human-machine interaction	E	SM	D, A
40	Ozkan-Ozen & Kazancoglu, 2021	QUAN	Workforce development (competences)	E, M	Not specified	B
41	Schneider & Sting, 2020	QUAL	Employees' attitudes	E, M	Various technologies	D
42	Schneider, 2018	LR	Managerial challenges, employee capabilities	E, M	Not specified	B, D
43	Selvarajoo et al., 2021	QUAL	Employee cooperation, skills, qualifications	E	Collaborative manufacturing	D
44	Shet & Pereira, 2021	LR	Managerial competences	M	Not specified	B, D, A
45	Shin et al., 2019	QUAN	Human versus machine decision making	E, M	Not specified	A
46	Singh et al., 2021	Mixed	Employee skills	E	Not specified	A
47	Stadnicka & Antonelli, 2019	QUAL	Human-robot collaboration	E	Human-robot shared workplace	B
48	Stentoft et al., 2021	Mixed	Workforce qualification, skills, motivation, and knowledge about I4.0	E, DE, M	Various technologies	B
49	Tortorella et al., 2021	QUAN	Employee involvement	E	Various technologies	A
50	Ukobitz, 2021	LR	Organizational change	E, M	Additive manufacturing	B
51	Vereycken et al., 2021	QUAN	Employee skills, employee involvement, job design	E	Various technologies	A
52	Zangiacomi et al., 2020	QUAL	Enablers, challenges, organizational issues	M	Various technologies	B, D