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Development and application of a maturity model for Industrial Agile Working

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ABSTRACT

In recent years, several companies approached agile working strategies to increase the resilience of their business. Agile work started spreading also to the manufacturing sector, thanks to the adoption of technologies that increasingly allow remote control of production systems. Nevertheless, agile working in the industry, namely Industrial Agile Working (IAW), requires organisational transformations and investments in technological innovations to guarantee its successful implementation. The first objective of this paper is to define the most relevant dimensions that affect the applicability of agile working practices in industrial contexts. The second objective is to develop an Industrial Agile Working Maturity Model (IAWMM) to measure the maturity of a company in adopting IAW practices. Starting from a set of dimensions identified through scientificic literature analysis, the IAWMM was tested by involving several companies in the manufacturing sector. The refined IAWMM was finally applied to a small sample of companies. The results report a good readiness of the companies concerning the knowledge and application of the key enabling technologies but still a low willingness concerning organisational change and flexible workforce management models. However, the IAW appears to be a promising strategy to promote a better workforce wellbeing and companies' efficiency and resilience.

1. Introduction

Over the years, due to the evolution and spread of new organisational trends, increasingly innovative technological tools, and the recent crisis due to the COVID-19 pandemic, companies around the world have been forced to make abrupt changes to their organisational and work management models (Gastaldi et al., 2014; Marino and Capone, 2021). One of the most significant examples of this ever-changing context is the introduction of Agile Working (AW) practices by many companies, ranging from public administration to, more recently, manufacturing (Gonçalves et al., 2021). Agile Working (sometimes referred also as Smart Working) represents an innovative approach to work organisation that gives the employee flexibility and autonomy in choosing the space, working hours and tools to be used for greater accountability for the results achieved individually and by the work team. Despite being moderately widespread in office and service-related employments, implementing such practices is much more difficult in the industrial context, specifically concerning operational roles strictly connected to production resources.

While the Agile Working concept gained significant prominence, especially during the pandemic, as a response to a temporary critical situation, numerous scholars have identified the enduring value of the COVID-19 experience in inspiring the development of novel approaches to enhance work organization and bolster employee satisfaction. In an examination of post-pandemic opportunities associated with agile and flexible work arrangements, a survey conducted in Germany by Schmidtner et al. (2021) revealed that remote work was perceived as a viable long-term solution by half of the participants. In portraying the "new normal at work" in the post-COVID era, Vyas (2022) emphasized the imperative for certain pandemic-driven practices, such as hybrid work, remote work, flexible workplace arrangements, and adaptable work schedules, to persist even beyond the constraints imposed by the pandemic. Ambrogio et al. (2022) conducted a comprehensive exploration of the applicability of Agile Working practices in shopfloor environments, positing it as an effective means to achieve a higher degree of workforce resilience and robustness—a matter of paramount significance, particularly in light of the evolving objectives of Industry 5.0 (European Commission. Directorate General for Research and Innovation, 2021).

Currently, the concept of Industrial Agile Working (IAW), broadly

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Table 1
Research stages, phases, methods and outputs.

		Phase 1. Knowledge acquisition	Phase 2. Diagnosis	Phase 3. Criteria setting
STAGE A Development of the IAW maturity model	**Role**	Assessing the value of the maturity model and leading to the identification of its components. Evaluation of the existing maturity models concerning agile working and Industry 4.0.	Collecting and systematising the judgement on the different classifications. Definition of the dimensions and subdimensions.	Definition of Maturity Levels.
	Methods	Scientific Literature Review	Consensus decision making	Consensus decision making
	Outputs	Existing maturity models refer to agile working.	MM dimensions and subdimensions.	Levels of maturity and questions.
	Paper section	3.1 & 3.2	4.1	4.1
		Phase 4. Implementation design	**Phase 5. Testing**	**Phase 6. Application**
STAGE B Application of the IAW Maturity Model	**Role**	Selecting the test companies. Defining the questions to be asked.	Executing the test of the IAWMM by interviewing 16 companies and receiving feedback. Tuning of the final version of the IAWMM.	Applying the IAWMM to the selected companies.
	Methods	Questionnaire	Semi-structured interviews	Structured interviews
	Outputs	Companies to involve in the IAWMM testing. First draft of IAWMM questionnaire.	Final version of the IAWMM.	Assessment of the IAW maturity level in the selected companies.
	Paper section	4.2	4.2–4.3	5

considered as the adoption of agile working practices in manufacturing and logistics operations, is still underdeveloped and adopted only by a limited number of companies (Cimini and Cavalieri, 2022). Nevertheless, the recent restrictions imposed by many national governments to face the COVID pandemic and to minimise the contagion risks in working environments pushed forward the debate about the potential of adopting such flexible working practices also in "blue collars" roles to avoid disruption in the production and ensure the business continuity. Moreover, it is being observed that more recently, even where COVID-related distancing rules have been relaxed, many companies are reflecting on continuing in the vein of the previous experience, leaving certain job profiles free to make flexible workplaces and hours (Schmidtner et al., 2021). However, the transition from a traditional work model, understood to be based on prefixed and standardised work schedules and workplaces across multiple job profiles, to a agile work model, customised to the needs of both the company and the workers themselves, is very challenging in several respects. First, it requires a change in human resource management from an organisational and managerial perspective (Raguseo et al., 2016). Secondly, it requires a cultural evolution of upper management and lower-level workers in terms of both leadership styles and autonomy mechanisms (Iannotta et al., 2020). Finally, it has already been noted how technology plays a key role in enabling and making profitable some remote and agile working practices (Russell and Grant, 2020).

In this context, our work aims to clarify and delineate the concept of Agile Working in industrial production, investigating what specific conditions may relate to this environment and what technological and organizational dimensions might enable its implementation with the goal of improving the satisfaction of industrial workers. Indeed, even-if the AW represents a well-established concept in the literature, its application to the industry is largely unexplored. Moreover, recently several empirical studies discussed and demonstrated the positive impacts of AW on workers satisfaction and motivation (Mazzucchelli, 2017), oftem by conducting case research in multiple working environments such as public administration (Zappalà et al., 2021), banks (Reunamäki and Fey, 2023) or telecommunication companies (Coenen and Kok, 2014). These applications foreshadow that potentially successful applications could be designed for the industrial sector as well. Therefore, by grounding on the current body of knowledge concerning AW including organizational, social and psychological perspectives, this study aims to contribute to the definition of future scenarios of Industrial Agile Working to be adopted in manufacturing contexts by answering the following research questions:

RQ1: Which are the most relevant company features that affect the applicability of agile working practices in industrial contexts?
RQ2: How can a company's maturity be measured in adopting Industrial Agile Working practices?

To answer these research questions, a literature review has been performed, and the core attributes of IAW have been identified and organised on three main dimensions, i.e. human, technology and organisation, as suggested by Cimini and Cavalieri (2022). Then, an Industrial Agile Working Maturity Model (IAWMM) was developed and refined with industrial stakeholders, and it was finally applied to measure the maturity level of seven manufacturing companies. From the application, meaningful insights emerged about the current challenges in adopting IAW in manufacturing contexts.

The remainder of the paper is organised as follows. Section 2 reports the methodology used to build the maturity model (MM) and to conduct the validation and application with industrial companies. Section 3 presents the background, defininig in detail the topics of AW and maturity models. Section 4 presents the developed model with a detailed description of the dimensions, sub-dimensions and maturity levels. Section 5 presents the results of the application of the model, discussing the main insights coming from the industrial application and drawing the conclusions of this research.

2. Methodology

The research procedure adopted is based on an adaptation of the two stages approach proposed by Gastaldi et al. (2018) and Rafael et al. (2020) that is developed taking into consideration also the previous existing maturity model-building methodologies provided by De Bruin et al. (2005), Becker et al. (2009) and Maier et al. (2012).

According to several authors, the development of maturity models can be considered a form of design science research (Becker et al., 2009; Mettler and Rohner, 2009), whose purpose is to create innovative artifacts that help address human and organizational challenges (Hevner et al., 2004). Pöppelbuß and Röglinger (2011) demonstrated the relevance of maturity model in the perspective of design science research, focusing on the importance of following its main relevant stages, such as conceptualization or validation.

Following a similar approach, the different phases that have been implemented for the present study are shown in Table 1. In particular, during stage A, the dimensions, levels and assessment tools are identified through the development of three different phases (i.e., knowledge acquisition, diagnosis and criteria setting). During stage B, the maturity

Table 2
Testing companies' demographics.

Company	Type	Sector	Dimension	Interviewee's role
A	Manufacturing	Electrical equipment	Large	▪Operations Manager ▪Innovation Manager
B	Manufacturing	Electrical equipment	Medium	▪Human Resources Manager ▪Operations Manager
C	Process	Chemical	Large	▪Human Resources Manager ▪Operations Manager
D	Manufacturing	Machinery	Medium	▪Human Resources Manager ▪Industrial Director ▪Information Technology Manager
E	Manufacturing	Machinery	Large	▪Human Resources e Organisation Manager
F	Manufacturing	Textile	Medium	▪Human Resources Manager
G	Manufacturing	Machinery for textile	Medium	▪Human Resources Manager ▪Industrial Director
H	Process	Chemical	Large	▪Human Resources Manager ▪Operations Manager
I	Process	Textile	Large	▪Human Resources Manager
L	Manufacturing	Textile	Medium	▪Human Resources Manager ▪Information Technology Manager
M	Manufacturing	Electrical equipment	Large	▪Human Resources Manager ▪Production Engineer ▪Business Process Manager
N	Manufacturing	Automotive	Large	▪Human Resources Executive Director ▪Production Manager ▪Business Process Manager
O	Manufacturing	Machinery	Medium	▪Human Resources Manager ▪Production Manager
P	Process	Steel production	Large	▪Human Resources Manager ▪Academy -training-Manager ▪ PhD Candidate -HR & Industrial Relations
Q	Manufacturing	Machinery	Medium	▪CFO -Human Resources Manager ▪Operations Manager
R	Process	Automotive	Large	▪Digital Factory Engineer

model is tested, modified and then applied to companies to perform the assessment.

2.1. STAGE A: Development of the IAW maturity model

Phase 1. Knowledge acquisition

In order to identify the already existent maturity models in the field of AW and Industry 4.0, an extensive literature review has been done, and the results have been reported in Section 3.2. This literature review aimed to understand the criteria used to define and select the dimensions and the levels by assessing the maturity model and identifying potential logic to group these metrics (Gastaldi et al., 2018).

For each of the reviewed MM, we analysed the characteristics, dimensions, levels, strengths, weaknesses, purpose and target audience to compare them and understand which of these aspects should be used in the development of the IAWMM.

Phase 2. Diagnosis

In this phase, we started from the analysed literature models and, through an iterative consensus decision-making process, we defined the dimensions and subdimensions to be presented to the companies.

As Rafael et al. (2020) stated, consensus decision-making is a very useful method for finding the best solution to a problem by allowing a group to evaluate the advantages and disadvantages of each alternative. In our case, we performed three virtual consensus sessions, lasting two hours, with an expert panel composed of five researchers. Three of the involved researchers are experts in manufacturing systems and Industry 4.0 technologies, while the remaining are experts in the organisation and human resource management field. Through the expert panel sessions, grounding on the different experiences of the researchers, the model dimensions' definition gradually converged towards three main dimensions and 19 sub-dimensions.

Phase 3. Criteria setting

In this phase, we have defined the maturity levels of the dimensions and sub-dimensions defined in phase 2. We have again applied consensus decision-making to agree on the maturity levels to be considered for each subdimension. Two consensus meetings have been conducted, lasting one hour and including only the authors.

2.2. stage B: application of the iaw maturity model

Phase 4. Implementation design

As the model was purely theoretical, it needed validation by industrial stakeholders. Therefore, sixteen companies were selected according to the dimensions and industrial sector. Given the socio-technical complexity of the IAW, only medium and large companies have been selected, with an equal balance between them. Then, companies in the process industry and manufacturing have been selected, ranging in the most representative sectors of the Italian industrial context. They are shown in Table 2.

During this phase, we have also defined the question to be asked during the assessment of the companies' maturity. They were designed to cover all the dimensions and subdimensions, to identify the respondent company's maturity level clearly and to collect feedback about the perceived importance of each dimension in relation to the IAW.

Phase 5: Testing

In this phase, we tested the IAWMM by interviewing the 16 selected companies using a semi-structured interview protocol. In most studies that define a maturity model for the analysis of a new artifact or model, the testing phase is usually conducted with only one company (Akdil et al., 2018; Rafael et al., 2020) or with a very limited number of companies (Colli et al., 2019; Santos and Martinho, 2020). Therefore, we do not believe that testing it initially with 16 companies may have compromised its validity. On the contrary, compared to valuable articles already published, it is an element that enhances the value of the conducted research. Table 2 shows the list of the companies and the interviewees' roles that provided interesting feedback concerning the

questions and results of the maturity models in this phase. To receive relevant insights from almost all the companies' technical and organisational perspectives, we interviewed two stakeholders, one from the HR department and one from the operations or production engineering.

In detail, the purpose of the interviews was to understand whether the proposed model was valid for describing and assessing the IAW phenomenon. All meetings took place through the online video communication platform "Microsoft Teams" and lasted between 60 and 90 min. Interviews were conducted involving at least two researchers to avoid bias in interpreting respondents' answers. During the interviews, each interviewee was initially asked to give a general introduction about the company. Then, processes, organisational factors and workers' tasks and attitudes were discussed based on a semi-structured protocol composed of ten questions.

After the testing session, the first version of the IAWMM was consequently modified, according to the interviewees' comments.

Phase 6: Application

Once we had tested and redefined the MM and the questions, we moved to its pilot application. In particular, five large companies were selected among the sixteen of the testing phase (companies A, B, L, M, O), and two additional companies that are partners of Company M were added to the sample. The two additional companies are large companies working in the same sector as company M, connected to it with a stable partnership. The small number of participants in this last phase of the research is due to the fact that the selection process was carefully conducted, taking into consideration several factors. Firstly, the companies' interest in the IAW topic was assessed, ensuring that they were genuinely interested in exploring this area. Additionally, it was important to determine whether the companies had already initiated internal discussions with their human resources department and employee representatives regarding the possibility of adopting IAW practices. This ensured that they were well-prepared and had a clear understanding of the potential benefits and challenges associated with the program. Furthermore, the companies' willingness to invest more time and effort in the evaluation process was considered, as they were required to conduct a second round of interviews. This additional step allowed for a more in-depth assessment of the candidates and provided an opportunity for the companies to gain further insights into their potential fit within their organization. Overall, the selection process was designed to identify companies that not only demonstrated interest in the IAW topic but also showed a proactive approach in engaging their employees and investing in the success of such initiatives. Also, in this case, meetings took place through the online video communication platform "Microsoft Teams" and lasted between 60 and 90 min with the same people interviewed during phase 5 (for the new companies, HR managers were interviewed). The results obtained from the interviews were reported in an Excel spreadsheet to get graphs that could give an overall view of the phenomenon. Based on these, appropriate considerations were made. Finally, we compiled a report as feedback for each company highlighting its strengths, weaknesses, suggestions for improvement and relative maturity level.

3. Background

3.1. From agile working to industrial agile working

Since the mid-2000 s', many companies started adopting ICT-enabled smart work practices to improve operational efficiency and corporate competitiveness (Ko et al., 2021). Through the years, different terminologies, such as Agile Working and Smart Working, have been created to refer to work practices exploiting technologies' potential to enhance the employees' "way of working", finally improving both well-being and productivity. Eom et al. (2016) refer to Smart Working (SW) as an alternative mean of organising work, employing computer-based technologies to enable labour activities anytime and anyplace. The same concept is reported by McEwan (2016), who added the "flexibility" perspective in approaching working activities. Some authors also refer to Agile Work to identify ways of working more flexibly by utilising new technology, including e-working (Russell and Grant, 2020). Nevertheless, in the literature, Agile Working concept has been also related to the organisational practices based on team planned routines that facilitate change oriented behaviours (Junker et al., 2023) or to company capabilities to adapt to changes by adopting agile mindset and leadership (Crnogaj et al., 2022).

Actually, to the purpose of this research, we adopt the most holistic perspective offered by one of the most cited and adopted definition of AW, namely the one provided by the Chartered Institute of Personnel and Development that consider it "an approach to organising work that aims to drive greater efficiency and effectiveness in achieving job outcomes through a combination of flexibility, autonomy and collaboration, in parallel with optimising tools and working environments for employees" (CIPD, 2008). In this definition, it emerges that the key principles of AW are autonomy and flexibility, which, combined with a proper revision of working tools and workspace organisation, can finally lead to higher performance in human work. Indeed, AW can be considered a completely new work culture that exploits new tools, processes and management strategies to provide workers with increased flexibility to perform their activities.

Iannotta et al. (2020) report how AW, increasing both productivity and job satisfaction, results in a "triple win" configuration for customers, employees and companies. The impacts of AW adoption on employees' well-being and the company business are widely discussed in Mazzucchelli (2017). According to empirical research, AW allows a better work-life balance, reducing stress and absenteeism and increasing the motivation and involvement of workers. At the same time, the company can benefit from a more effective use of time, increasing work effectiveness and productivity.

Despite the concept of AW being assumed as a synonym for teleworking in the past, it has become evident in the academic literature that AW integrates and exceeds this previous concept (Torre and Sarti, 2019). If teleworking mainly consists in moving the place of work but with a rigid scheme in the work time and tools, the AW adopts a paradigm change by promoting the empowerment of the employees in defining autonomously where, when and how to perform the work tasks (Cimini and Cavalieri, 2022). Moving from the concept of simply working outside the conventional workplace and communicating through telecommunication, the AW then grounds on three pillars: discretion, responsibility and flexibility (Sarti and Torre, 2017). Therefore, to truly practice AW, it is required to overcome the association that it is only remote work, and, rather, interpret it as a path of transformation of the organisation and the way people experience work.

Clapperton and Vanhoutte (2014) propose a 3B model to guide the implementation of AW practices, whose main dimensions are: i) Behaviour, i.e. organisational culture; ii) Bytes, i.e. technologies and operational tools; iii) Bricks, i.e. workspaces. This suggests that updated corporate policies of internal organisation and management of human resources are requested, as well as new guidelines to regulate working hours and workplaces, together with a change in corporate culture and leadership styles. Moreover, the adoption of AW practices involves the worker attitude since it is not only an executive and operational mode but claims for an "entrepreneurial" approach and mentality from the worker in managing activities and achieving results. Finally, since the first introduction of the AW concept, technology, particularly ICT, has been recognised as one of the most important enablers since IT solutions allow collaboration and flexible interactions among workers (Raguseo et al., 2014).

Therefore, many scholars address the AW as a multidisciplinary and socio-technical topic that involves at the same time human, technology and organisational issues. Indeed, as Bednar and Welch (2020) state, AW requires optimal balance and coherence between technologies, skills, social and business imperatives.

In recent years, also in consideration of the fast-paced evolution of

technology, scholars and practitioners started a discussion about the possibility of extending AW practices into the production environments. The concept of IAW refers to "all the AW methods and practices employed to enable flexible working activities for factory job profiles, such as the ones working in the production, logistics and maintenance" (Cimini and Cavalieri, 2022). Thus, IAW can be understood as the application of AW practices in manufacturing through smart technologies that enable flexibility and remote management of production planning, control, and management activities.

According to the analysis provided by the MADE Competence Center (2020), the IAW grounds on a set of methods and technologies that enable the flexible and remote management and execution of operational processes (e.g., production advancement, quality control, maintenance control, execution of logistical activities within the plant,…). It requires changes in the socio-technical system (people, work organisation, technologies and processes) to make operational processes more flexible, reconfigurable and safer also for elder workers or workers with disabilities while maintaining high productivity.

Compared to the office scenario, in which the most of the research about AW has been developed so far, the factory scenario presents several issues that have prevented the adoption of such practices through the years. In particular, to identify the main differences between office and factory scenario, it is possible to refer to the dichotomy between "white collars" and "blue collars", whose work characteristics have been marked as significantly opposite in the past. Traditionally, blue collars perform physical work on the shopfloor, while white collars include professionals performing desk-bound work (Su et al., 2020). Also, white collars' jobs are often more complex, including mental and cognitive tasks, while blue collars perform mainly routinized tasks, that do not require high skills (Hu et al., 2010). On the other side, even if white collars jobs are more challenging, they are physically lighter and the risk of accidents in smaller than blue collars one (Toppinen-Tanner et al., 2002). Moreover, blue collar work is often referred to hourly waged job and tends to be closely supervised, while white collar work, being more brain-work based on data like words, number, figures, ideas, could be more flexible in the work time organisation (Najjar, 2017; Schreurs et al., 2011). All these aspects resulted in wide discussions addressing AW practices in white collars-office jobs and less or null consideration about flexible work practices for blue collars working in factories. Nevertheless, the latest technological innovations brought by the Industry 4.0 paradigm have triggered a rethinking of the traditional work design, narrowing the differences from blue collars and white collars. Waschull et al. (2020) explore in depth how the blue collars work is evolving in relation to new digital technologies realising automation, virtualisation and flexibilization. In particular, blue collars are expected to increase the number of complex cognitive jobs, also assuming the role of strategic decision-making or problem solvers.

In this scenario, IAW becomes a real opportunity, that deserves proper investigation. Indeed, to move towards such an approach, adopting smart technologies (also referred to as Industry 4.0 technologies) will be crucial. In particular, IAW would benefit from the concept of Smart Operators or Operators 4.0, whose capabilities are enhanced and enriched by connected technologies and smart devices (Meindl et al., 2021). For instance, Frank et al. (2019) directly refers to smart work to discuss all the technologies that enable remote monitoring and remote execution of machinery, such as IoT, analytics and virtual reality, and that can be useful to introduce flexibility in the workplace of the operators that could be able to supervise production processes from anywhere inside and outside the factory. Other examples are augmented reality tools that make possible remote training and maintenance activities (De Pace et al., 2018). Widening the perspective, IAW could be more effectively implemented where digital twins of products, production processes and manufacturing systems are available (Maddikunta et al., 2021). Finally, wearable devices (e.g. smartwatches, smart glasses, smart clothes) can be helpful in exchanging information between the operators and between operators and machines by aiding remote communication and collaboration (Kong et al., 2018).

Despite sometimes the concept of IAW has been solely related to technology adoption (as in the case of Frank et al. (2019)), according to our perspective, to address the IAW, a rethinking of the organisational practices is also crucial, i.e. a revision of the organisational structure, which entails the macro-structure (organisational chart), the

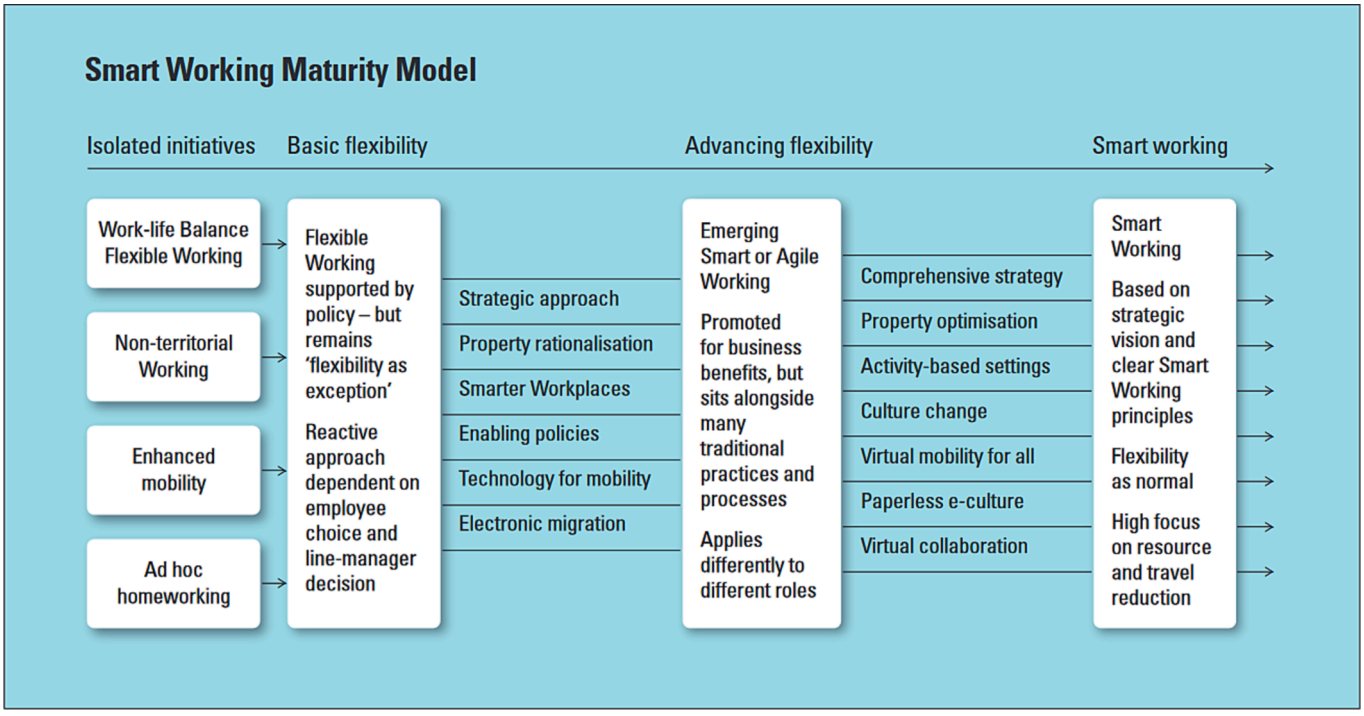

Fig. 1. Lake's Maturity Model ().
Source: Lake and Dwelly, 2014

mesostructure (virtual and non-virtual work groups) and the micro-structure (job design and tasks), as well as business processes and operational mechanisms, especially those related to human resource management (Dossena and Mochi, 2020).

Therefore, several barriers to the adoption of IAW exist and concern both the perspectives of workers and organisations. Workers should adopt a more proactive and responsible approach to managing their working activities, while organisations are required to promote a change in mindset and culture to adopt management by objective working models. Also, companies should undertake investment in technologies and digital devices, reorganising workspaces and tools. All these barriers currently prevent most companies from addressing AW practices in the factory environment.

Significant investigations are needed to understand the crucial factors in promoting the implementation of IAW. Indeed, industrial companies require to be guided in the identification of the opportunity of including agile working practices in their processes since, currently, the awareness about the topic is low. Nevertheless, to successfully adopt IAW, a preliminary analysis must be performed to assess the company's maturity, conducting a holistic evaluation of all the socio-technical dimensions that play a relevant role. To this purpose, maturity models can be useful and are widely discussed in the following subsection.

3.2. Maturity models

Over the years, maturity models (MM) have been developed to assist organisations in assessing the maturity, conceived as the competency, the capability or the level of sophistication, of a selected domain based on a pre-defined and comprehensive set of dimensions (De Bruin et al., 2005). Kohlegger et al. (2009) highlight the relevant role of maturity models as tools used to assess the maturity capabilities of some aspects to take the most appropriate actions to bring these elements to a higher level of maturity. According to Proença and Borbinha (2016), over the years, these tools have proven to be very effective in assessing some of the main aspects of an organisation. Indeed, maturity models can be used as a comparative basis for improvement (Fisher, 2004) to increase the capability of a particular area within the company (Paulk et al., 1993).

Maturity models are composed of three main elements: dimensions, levels and assessment tools (Gastaldi et al., 2018). A dimension represents the characteristic of an organisation/process or the capability that is measured; therefore, maturity models can be one-dimensional but most frequently are multi-dimensional, offering a structured assessment of the company's capabilities in different domains that can be evaluated independently on scaled maturity stages (Wendler, 2012). Levels are the maturity stages that the dimension assumes (Gastaldi et al., 2018). Generally, the lower level represents the initial state, a company with few competencies in the domain under consideration. In contrast, the higher level represents full maturity in the domain under consideration. Advancing in the levels' evolution path involves a continuous progression of the company's capabilities (Becker et al., 2009). Assessment tools are qualitative and quantitative methods to collect data from the company (such as questionnaires and scoring models) (Fraser et al., 2002).

To meet this research's purpose and follow the socio-technical perspective of the IAW phenomenon, we reviewed the available maturity models in two domains: smart/agile working and smart manufacturing/industry 4.0.

Regarding the concept of Smart or Agile Working, few models have been found.

The model proposed by Lake (2013) aims to identify the maturity status of an organisation to implement Smart Working (SW) practices, describing the following four levels (Fig. 1):

- Isolated Initiatives. At this level, mobile working practices and employee interaction begin to be implemented.

Table 3
Industry 4.0 maturity models.

Maturity model	Dimensions											
	Strategy	Leadership	Customers	Products	Operations/ Process	Human(People/ Culture/HR)	Organisation	Governance	Technology	Business model	Services	Connectivity/ Infrastructure
(Ganzarain and Errasti, 2016)	X											
(Lichtblau et al., 2015)	X			X	X	X	X				X	
(Leyh et al., 2016)				X					X		X	
(Schumacher et al., 2016)	X	X	X	X	X	X		X	X			
(De Carolis et al., 2017)					X		X		X			
(Gökalp et al., 2017)					X	X	X	X	X			
(Schuh et al., 2017)				X		X	X		X			
(Akdil et al., 2018)	X			X	X	X			X	X		
(Sjödin et al., 2018)					X	X			X			
(Canetta et al., 2018)	X			X	X	X			X		X	
(Leineweber et al., 2018)						X	X		X			
(Colli et al., 2019)						X		X	X	X		X
(Santos and Martinho, 2020)	X			X	X	X	X		X		X	X
(Rafael et al., 2020)	X			X	X						X	X

- Basic Flexibility. The organisation incentivises the adoption of corporate policies and programs intending to create a smarter work environment. There is still no unambiguous SW practices implementation strategy within the company.
- Advancing Flexibility and the beginning of SW. The implementation strategy becomes more defined, and use is made of enabling technologies to incentivise collaboration and information sharing among workers through remote work and a layout of the company's internal spaces that support these practices.
- SW. Full implementation of SW practices. The worker enjoys the complete trust and is evaluated by goals achieved. People also collaborate and communicate remotely. SW is fully integrated into business strategy.

As shown in Fig. 1, in Lake's model, several dimensions enable the transition from a lower to an upper level, involving many socio-technical aspects, from company strategy and policies to technologies and workplaces.

The model proposed by the Smart Working Observatory of the Politecnico di Milano (Crespi, 2014) aims to provide a roadmap for the implementation of SW practices in an enterprise considering two extreme levels, i.e. traditional work vs smart work, and defining the evolution from the former to the latter through four dimensions:

- *Technology*. Proper implementation of Smart Working practices goes through appropriate mobile and digital technologies adoption.
- *Policy*. Special attention must be paid to reviewing organisational policies that foster collaboration, communication, and flexibility in both space and time.
- *Layout*. Space within the organisation is of paramount importance as proper space layout is necessary to promote collaboration and inspiration.
- *Leadership*. Leadership plays a key role, as it is essential to change the logic of supervision and control by promoting greater autonomy of workers, encouraging empowerment and a working style based on achieving objectives.

Finally, the model proposed by Clapperton and Vanhoutte (2014) is presented as a guide to support companies in introducing Agile Working practices. It does not provide specific maturity levels but an organised overview of the three main dimensions and 13 subdimensions that must be considered to implement AW. They are:

- *Bricks*, which include *workspace management*, *workspace design*, *sustainability and mobility*.
- *Bytes,* which include devices, information, knowledge, communication, and *collaboration*.
- *Behaviours*, which include *results-oriented management*, *results-oriented work*, *trust and autonomy*, *personal satisfaction and work-life balance*, *culture and motivation*.

Reviewing the maturity models pertaining to the AW literature, it has been observed that they focus mainly on work organisation and human resource aspects, while they lack a clear vision about the technological enablers of AW, that are especially relevant in the industrial scenario. This gap is partially addressed in the work of Cimini and Cavalieri (2022), that, describing the enabling factors for a successful implementation of IAW, present a socio-technical model organised into three categories, i.e. Organisation, Technology and Human.

Considering the topic of Industry 4.0 and digitalisation in the manufacturing context, many maturity models have been retrieved in the literature. Also, in this case, the majority of them grounds on a set of socio-technical dimensions. A summary of the reviewed models and the related dimensions is presented in Table 3.

The table shows that the most cited dimensions are Technology, People/Culture/Human Resources and Operations/Process. This

Table 4
Maturity model subdimensions – first proposal.

	Subdimension	Description	Reference
Organisation	Organisation ecosystem	It refers to the interaction and collaboration of the organisation with other partner companies in the value chain.	(Santos and Martinho, 2020)
	Resilience	It refers to the capability of the company to face disruptions and external changes.	(Cimini and Cavalieri, 2022)
	Hierarchical structure	It refers to an organisation's architecture in terms of the number of hierarchical levels.	(Akdil et al., 2018)
	Control and supervision	It refers to the approaches adopted by managers to supervise the work of subordinates.	(Schumacher et al., 2016)
	Information sharing	It refers to the communication inside the companies.	(Clapperton and Vanhoutte, 2014)
	Decision-making process	It refers to the approaches to decision-making (e.g., centralised or decentralised).	(Schuh et al., 2017)
	Temporal flexibility	It refers to the possibility of choosing the time and duration of work.	(Lake, 2013)
	Spatial flexibility	It refers to the possibility of working from different workplaces or workstations.	(Lake, 2013)
Technology	Information digitisation	It refers to the degree of digitisation of company documents.	(Leyh et al., 2016)
	Process digitalisation	It refers to the use of digital tools in manufacturing processes.	(Colli et al., 2019)
	Process automation	It refers to the use of automation technologies in production.	(Lichtblau et al., 2015)
	I4.0 technologies' adoption	It refers to the specific adoption of Industry 4.0 (I4.0) technologies in the production (i.e., IoT, autonomous robots, collaborative robots, big data collection and analysis, cloud computing, augmented reality, digital twin and virtual factory, wearable devices)	(Schumacher et al., 2016)
Human	Autonomy	It refers to the worker's capability to perform autonomously the work tasks assigned.	(Cimini and Cavalieri, 2022)
	Responsibility	It refers to the responsibility of the single operator and the manager's team to reach the target objectives in terms of productivity.	(Lake and Dwelly, 2014)
	Technology usage	It refers to the need to use technological devices to perform tasks.	(Torre and Sarti, 2019)
	Tasks' content	It refers to the main content of the working activity (i.e. manual, cognitive, managerial)	(Lund et al., 2020)
	Flexibility and polyvalence	It refers to the capability of workers to perform multiple tasks on multiple workstations (i.e. adoption of job enlargement and job	(Aderibigbe, 2021)

(*continued on next page*)

Table 4 (*continued*)

	Subdimension	Description	Reference
		enriching strategies) based on a learning orientation	
	Soft skills	It refers to the level of soft skills (e.g. memory, problem-solving, negotiation) needed to perform the work activity.	(Santos and Martinho, 2020)
	Workers' engagement	It refers to the level of involvement and proactive participation of the workforce in the organisation's goal setting and providing suggestions and feedback for production improvements.	(Marino and Capone, 2021)

suggests that even in the digital transformation process of manufacturing companies, the orchestration in the evolution of technologies and human aspects is required.

All the previously presented models have been taken as a reference to build the Industrial Agile Working maturity model that will be discussed in the following sections.

4. A maturity model for Industrial Agile Working

This section will present the maturity model for implementing IAW practices with a description of the dimensions, sub-dimensions and maturity levels. The presented model is descriptive in nature; that is, it aims to measure the "as-is" situation of specific organisations (Becker et al., 2009) regarding the implementation of IAW practices. Since the application of AW practices to all those office jobs has already been covered in the literature, while the field regarding the applications of the aforementioned practices in the factory environment is almost unexplored, the model was designed to be applied to all those companies of any size that operate in the industry.

The creation of the maturity model was iterative, as explained in the previous methodology section. Therefore, a first proposal of the model's dimensions and the number of levels is reported in Section 4.1. The results of the testing conducted in industrial companies are discussed in Section 4.2. In Section 4.3, the final dimensions and the levels of the IAW maturity models are reported.

4.1. First model proposal

Based on the relevant elements collected in the literature, the three dimensions of Organisation, Technology and Human were chosen according to the widely used HTO model (Dregger et al., 2016), and nineteen subdimensions were consequently inductively identified by the authors in the scientific literature analysed to assess the most relevant company features to consider when dealing with IAW practices. In particular, the subdimensions identification followed a two-stage approach. First, each author independently analysed the same set of papers and inductively defined his/her own list of subdimensions. After a review of the lists and a discussion among the authors, the final subdimensions list was defined. This second stage highlighted the substantial stability of the subdimensions as there were few disagreements. These few disagreements were resolved by the authors on a case-by-case basis. The results of the subdimensions identification are reported in Table 4, recalling the concepts used in the reviewed maturity models about Industry 4.0 and Agile/Smart Working.

4.2. Testing

After the definition, the IAW dimensions and subdimensions were discussed with the industrial stakeholders. They provided relevant feedback about the possibility of simplifying the model by unifying some dimensions referring to similar concepts. They also suggest including new subdimensions considered of utmost importance in the industry to enable the implementation of IAW.

Concerning the *Organisation* dimension, many of the interviewees agreed to define a single subdimension, called *Organisational structure*, which includes all the aspects related to the macro-organisation, encompassing, therefore, the *hierarchical structure*, the approach of the company to external collaborations, i.e., *organisation ecosystem*, and management of disruptions, i.e. *resilience*. The interviewees discussed that, nowadays, for a company to survive and remain competitive in the marketplace in increasingly variable and unpredictable contexts, its organisational structure must be flexible and dynamic. Resilience, flexibility and dynamism from an organisational point of view are required elements for dealing with any change. They are characteristics an organisation must necessarily have to introduce IAW practices. During the interviews, we found that the more flexible and dynamic an organisation was, the easier it was for the managers interviewed to imagine some form of flexibilization of operators' work activities.

Similarly, the companies explained that the three subdimensions called *control and supervision*, *information sharing* and *decision-making process* were strictly connected. According to managers, to talk about the flexibility of work, autonomy and empowerment of operators, it is necessary to adopt models of leadership based on working by objectives: the focus must be on the results achieved by departments or teams and not on the working hours, productivity or absenteeism of the individual. To allow this, systems and mechanisms for supervising and controlling workers must change, evolving from models of control, verification and evaluation to models based on autonomy and trust. In turn, this entails a more decentralised approach to decision-making processes and extensive use of delegation mechanisms. The transparency of information and decision-making processes emerged during several interviews as well. According to the managers, to work according to AW paradigms, there must be collaboration, interpersonal and inter-functional sharing and confrontation, and information transparency at any level. All these aspects have been then summarised in a new subdimension called *leadership*. Finally, many interviewees recognised that IAW should be adopted as a strategic evolution in the company strategy at large, thus proposing to introduce a new subdimension called *strategy*, which represents the level of importance of IAW in the company business strategy. This subdimension has the same meaning as the strategy dimension presented in several Industry 4.0 maturity models (see Table 1).

Considering the *Technology* dimension, the managers fully agreed with our definition of *information digitisation*, *process automation* and *I4.0 technologies' adoption*. Conversely, they demonstrated high interest in a better investigation of the *process digitalisation*. Indeed, they discussed that a key determinant of the possibility of introducing flexible work models is the type of production process. According to the managers we spoke with in this regard, to be able to think about temporal and spatial flexibility of factory work, systems organised as manufacturing cells, individual workbenches, islands or assembly benches, and stand-alone workstations would be preferable to manufacturing and assembly lines, with rigid handling systems. In these factory configurations, by means of buffers, it would be easier to manage and execute different process steps flexibly, decoupling them from a rigid production flow.

For this reason, we decided to develop two separate subdimensions referring to the features of both production and logistics systems, i.e. *process characteristics* and *logistics systems*. Furthermore, the companies highlighted the importance of cybersecurity as a critical technological aspect they experienced during the AW applied to office roles during the pandemic. According to their perspective, setting and implementing correct cybersecurity strategies is very relevant to allow flexible working activities both in office and factory roles since data collected from assets, products and people must be managed in the most secure way to prevent stealing or damaging confidential data. A new *cybersecurity* subdimension has been added and evaluated, according to Shojaifar and

Table 5
Industrial Agile Working Maturity model subdimensions.

	Subdimension	Level 1	Level 2	Level 3	Level 4
Organisation	**Organisational structure**	Rigid, hierarchical and bureaucratic organisation characterised by a closed system (i.e., isolated from the external environment) and low resilience.	Organisation that is formally vertical but operationally horizontal, characterised by an open system (i.e., interacting with the outside world) and a reasonable degree of resilience.	Formally and operationally horizontal organisation, characterised by an open system and a high degree of resilience.	–
	Temporal flexibility	Rigid and imposed working hours.	Time slot flexibility for the start and end of the working day.	Flexibility of the length of the working day.	–
	Spatial flexibility	Management and execution of activities in presence.	Remote task management and execution in presence.	Remote task management and execution.	Flexibility and autonomy in managing and executing tasks in-person or remotely.
	Leadership	Within the organisation, the hierarchical structure prevails. Workers receive orders and instructions not motivated by the manager or management; therefore, there is no communication between workers and managers. Workers do not enjoy autonomy and work under the close supervision of the leader.	The leadership style is based on the motivation of workers, albeit always subject to orders and instructions. The organisation's command structure is still strongly hierarchical; however, at this stage, a first form of communication and relationship with the workers can be glimpsed.	The leader offers help and support to workers, communicating with them and involving them directly before making a decision. The manager begins to experiment with forms of remote supervision, leaving workers more autonomy.	Workers enjoy complete autonomy and are evaluated solely on their performance. The leader trusts the workers and delegates them as many tasks as possible.
	Strategy	IAW is not considered in the corporate strategy.	IAW is seen in the background of the corporate strategy.	IAW is largely considered in the corporate strategy.	IAW is an integral part of the business strategy.
Technology	**Process characteristics**	Workstations are strongly coupled to each other. The production rhythm of the downstream stages is highly dependent on the rhythm of the upstream stages (e.g., assembly lines with defined cycle time).	The workstations are interdependent, although there is the possibility of creating inter-operational buffers (e.g., semi-automatic lines with small intermediate buffers, departmental production systems or manufacturing cells).	Workstations are decoupled from each other and work at different production rates (e.g., manual assembly islands and stand-alone manufacturing systems).	–
	Logistics systems	Handling systems that are extremely constrained in their routes (e.g., rigid conveyors, such as roller conveyors, belt conveyors, chain conveyors, etc.).	Handling systems constrained to pre-defined routes that can be changed by re-planning transport (e.g., front-end forklift trucks, reach trucks, pallet trucks, etc.).	Handling systems not bound to pre-defined routes can also be highly reconfigured automatically (e.g., AGVs).	–
	I4.0 technologies' adoption	No technology adopted.	At least 3 technologies adopted.	At least 6 technologies adopted.	–
	Information digitisation	Most documents are in paper format and are organised in physical archives.	Documents are partly in paper format and partly in digital format, but there is no cloud-based sharing system.	Documents are largely digitised and are accessible by the company's workers through the use of internal servers.	Data and information are all digitised, accessible and sharable from inside and outside the company, thanks to cloud systems.
	Cybersecurity	Cybersecurity policies are partially written and limited to certain areas of interest.	Cybersecurity policies are partially written for all the areas of interest. Presence of a Chief Information Security Officer (CISO).	Cybersecurity policies completely developed. Presence of a CISO and cybersecurity IT infrastructures.	–
	Process automation	Processes are all manual.	Manual processes with the support of automated systems (collaborative robots).	Automated processes, remotely controllable and programmable machines, remote maintenance, testing and monitoring.	Autonomously, intelligently and adaptively managed processes.
Human	**Responsibility**	The achievement of company goals and results is the responsibility of the management figures.	The work team (workers only) is responsible for achieving the set goals.	Workers are free to manage and organise their work and responsible for achieving their own goals.	–
	Tasks' content	Physical and practical work content and closely related to product processing.	Physical work content, with more cognitive tasks related to data collection, processing and analysis.	Practical tasks are mainly performed by machinery, while the cognitive content of the operator increases.	–
	Polyvalence	Low level of autonomy and polyvalent skills of the operators.	Limited autonomy and diversified skills in the workforce enable job enlargement strategies.	Experienced workforce with a medium level of autonomy and recognised operators' skills at the company level.	Complete workers' autonomy and structured job enlargement and enrichment strategies.
	Teamworking	No inclination to work in a team and each employee carries out their task individually.	Information sharing and collaboration between employees take place purely face-to-face.	Information sharing and collaboration between employees occur purely in person, with the possibility of working remotely.	Employees can work both in presence and remotely. Good inclination to use platforms for remote communication and collaboration.
	Performance assessment	Difficulty in measuring all performance indicators at a distance.	Difficulty in measuring only some remote performance indicators.	No difficulty in measuring all remote performance indicators.	–

Jarvinen (2021).

Finally, concerning the *Human* aspects of the IAW, in the experience of companies considering this aspect, the various formal and informal activities for involving and listening to workers play a crucial role. Allowing workers to express their ideas, propose improvements, point out problems, involve them and make them participants in decisions that affect the life of the organisation are all elements that would seem to foster workers' sense of belonging to the organisation and, thus consequently their empowerment with regard to what the company's goals are, incentivising workers to be autonomous. To this purpose, the *autonomy* and *workers' engagement* subdimensions have been included in the *responsibility* and *teamworking* subdimension. Furthermore, interviewees agreed that a relevant element to facilitate some form of flexibility in operators' work is undoubtedly an increase in the cognitive content of their tasks. This is strictly related to technological devices that enable process and machine supervision, data analysis and reporting activities, thus increasing the cognitive content of factory workers' tasks.

For this reason, *technology usage* was included in the *tasks' content* subdimension. Similarly, the managers suggested considering that the competences required to workers are evolving towards a mix of hard and soft skills, and the workforce is increasingly required to be polyvalent. For this reason, the final *polyvalence* subdimension involves skills and job enlargement/enrichment strategic approaches to work organisation. Finally, the HR managers suggested including a new subdimension related to developing new forms of performance measurement for workers adopting AW models (*performance assessment*). The way employees' performance is evaluated should move from a logic of evaluation based primarily on working time to one based on the achievement of goals on time, therefore requiring transparent systems for evaluating employee goals and productivity, easy to use even remotely.

4.3. Final maturity model

4.3.1. Dimensions' maturity levels

As a result of the testing phase and the feedback gathered from the companies, both some dimensions and their levels were modified, as explained in section 4.2 above. Based upon these modifications, the final version of the IAWMM was reached. For each dimension's level, a question has been produced with three or four possible answers (depending on the number of levels planned for the dimension under consideration) that reflect the increasing level of maturity. The expert panel has revised all questions. In particular, Table 5 shows the subdimensions and maturity levels defined for the dimensions present for each of the three dimensions identified.

4.3.2. Assessment method and IAW maturity level

The maturity levels are intended to indicate the state of maturity in the introduction of IAW within the company. Based on the literature, it was decided to develop four maturity levels (De Bruin et al., 2005). The definition of the different values defining the maturity levels was developed in different steps that contributed to defining the assessment method used for the IAWMM implementation. Initially, for every subdimension i a relevance $R_i \in [1,3]$ was assigned according to its importance for the implementation of IAW practices. Then, for each subdimension, a maximum score S_{max} was defined as:

$$S_{max} = R_i \times \frac{100}{\sum_{i=1}^{N} R_i} \quad (1)$$

in which N represents the total number of sub-dimensions considered in the maturity model. The maximum score S_{max} was then normalised based on the maximum number of levels for each subdimensions (L_{max}), and consequently, the final score s_i for the sub-dimension i is given by:

Table 6
Dimensions and sub-dimensions max scores and relevances.

Dimension and sub-dimensions	R_i	L_{max}	S_{max}
1. Organisation			**34,3**
1.1 Organisational structure	2	3	5,7
1.2 Time flexibility	3	3	8,6
1.3 Workspace flexibility	3	4	8,6
1.4 Leadership	2	4	5,7
1.5 Strategy	2	4	5,7
2. Technology			**31,4**
2.1 Process characteristics	3	3	8,6
2.2 Logistics systems	1	3	2,9
2.3 I4.0 technologies' adoption	2	3	5,7
2.4 Information digitisation	2	4	5,7
2.5 Cybersecurity	2	3	5,7
2.6 Process automation	1	4	2,9
3. Human			**34,3**
3.1 Responsibility	2	3	5,7
3.2 Tasks' content	3	3	8,6
3.3 Polyvalence	3	4	8,6
3.4 Teamworking	2	4	5,7
3.5 Performance assessment	2	3	5,7
Total			**100**

$$s_i = \frac{S_{max}}{L_{max}} \times L_i \quad (2)$$

Where L_i represents the Level reached by the company analysed for the sub-dimension I to evaluate.

The different values assigned to the relevance R_i were based on what emerged from the literature and the testing phase with industry stakeholders. Moreover, the relevance R_i was chosen also considering that the sum of the maximum points for all the sub-dimensions had to be a maximum of 100. We have then applied consensus decision-making to agree on the different value R_i to be considered for each subdimension. Only one consensus meeting has been conducted, lasting one hour and including only the authors. Table 6 shows the different dimensions and the score assigned to each sub-dimension.

Concerning the choice of the relevance R_i, during the testing phase, several industrial stakeholders highlighted that, in their perspective, the industrial implementation of AW requires higher efforts in the organisational and human aspects, which then have been rated more relevant compared to the technological one. In particular, they suggested that automation in processes and logistics systems do not have significant effect in the choice of implementing flexible working models ($R_i = 1$), while they supported that flexible organization in the work space and time as well as the tasks' content and operator polyvalence are crucial to enable the implementation of AW.

The total IAW maturity index (IAWMI) reached by the company analysed is finally given by:

$$IAWMI = \sum_{i=1}^{N} s_i \quad (3)$$

The distribution of the different IAWMI values between the various maturity levels was obtained, starting from 29.6 or the minimum achievable score up to 100 or the maximum score, as stated in Table 7.

5. Model application

To test the model's applicability, a pilot application of the IAW maturity model was developed by involving seven manufacturing companies located in the North of Italy. The selection and motivation process leading to this sample definition was explained in Section 2.2. The final results of the calculated IAWMI are reported in Table 8 and represented in Fig. 2.

Company C and Company G are "Early adopter" companies, both working in the electromechanical sector. Significant improvements are

Table 7
Industrial Agile Working Maturity Levels.

Maturity Level	IAWMI	Definition
1 - Beginner	30 < IAWMI < 47,5	The organisation is rigid, hierarchical and bureaucratic. No temporal and/or spatial flexibility is given to employees who, for reasons related to the content of the job and the level of automation of processes, are forced to stay at their workstation within the plant to work. Employees have no digital competence and are evaluated based on the working hours, not on the results achieved.
2 - Early Adopter	47,6 < IAWMI < 65	The organisation is less rigid and less vertical. The space in the plant, as well as the technological level of the machines, allow an initial flexibility of time, but the type of tasks is still closely linked to work at the workstation. Workers possess good digital skills; they are still evaluated according to the hours worked and not based on results, but they begin to be given more responsibility.
3 - Intermediate	65,1 < IAWMI < 82,5	The organisation begins to be less and less rigid and vertical. The spaces in the plant, as well as the technological level of the machines, allow good flexibility of time and a beginning of space flexibility because workers' tasks do not depend entirely on whether or not they are at their workstations. The concept of evaluation by objectives begins to be introduced within the company due to the greater autonomy and empowerment of workers with good digital skills.
4 - Champion	82,6 < IAWMI < 100	The organisation is completely horizontal and characterised by an open system. Thanks to the automation of processes and the use of Industry 4.0 technologies, workers can also work effectively outside their workstations, deciding on their own time and space. Workers are characterised by excellent digital skills and act completely autonomously as they are evaluated solely based on the results achieved individually and by the work team.

Table 8
Results of the IAW maturity model application.

Company	$S_{Organisation}$	$S_{Technologies}$	S_{Human}	IAWMI	Maturity level
A	24,9	27,5	30,7	83,1	Champion
B	17,4	22,4	22,9	62,6	Beginner
C	12,6	18,8	15,7	47,1	Early adopter
D	9,8	24,2	24,9	58,8	Beginner
E	21,0	25,5	20,7	67,1	Intermediate
F	15,2	27,4	20,0	62,6	Beginner
G	12,6	18,8	15,7	47,1	Early adopter

needed in the *organizational structure*, *time* and *workspace flexibility*, and workers' *responsibility*. The only sub-dimension in which they achieved the highest level is *information digitization*. Three companies positioned at the "Beginner" level: B, D and F. Again, the sub-dimensions in which the companies scored lowest are *time* and *workspace flexibility* as well as *tasks' content*. Instead, the levels in which they scored higher are *information, digitization* and *teamworking*. The "Intermediate" level contains company E. The company placed at this level despite scoring low for the sub-dimension employee *responsibility*, which is one of the factors considered most relevant for IAW practices.

Nevertheless, the company ranked high for several dimensions, such as *leadership*, *I4.0 technologies' adoption*, and *cybersecurity*. Only Company A could rank in the highest position of the pyramid, at the "Champion" level. This was possible by achieving the highest levels in *strategy, information digitization, I4.0 technologies' adoption, cybersecurity, responsibility* and *team working*.

Interviews showed that, currently, the most difficult subdimensions to implement are those related to *time and workspace flexibility* and *organizational structure*, which struggles to overcome the classic model of a rigid, hierarchical and bureaucratic organization characterized by a closed system and low resilience. At the same time, it is one of the factors in which all surveyed companies seek to improve with the minimum

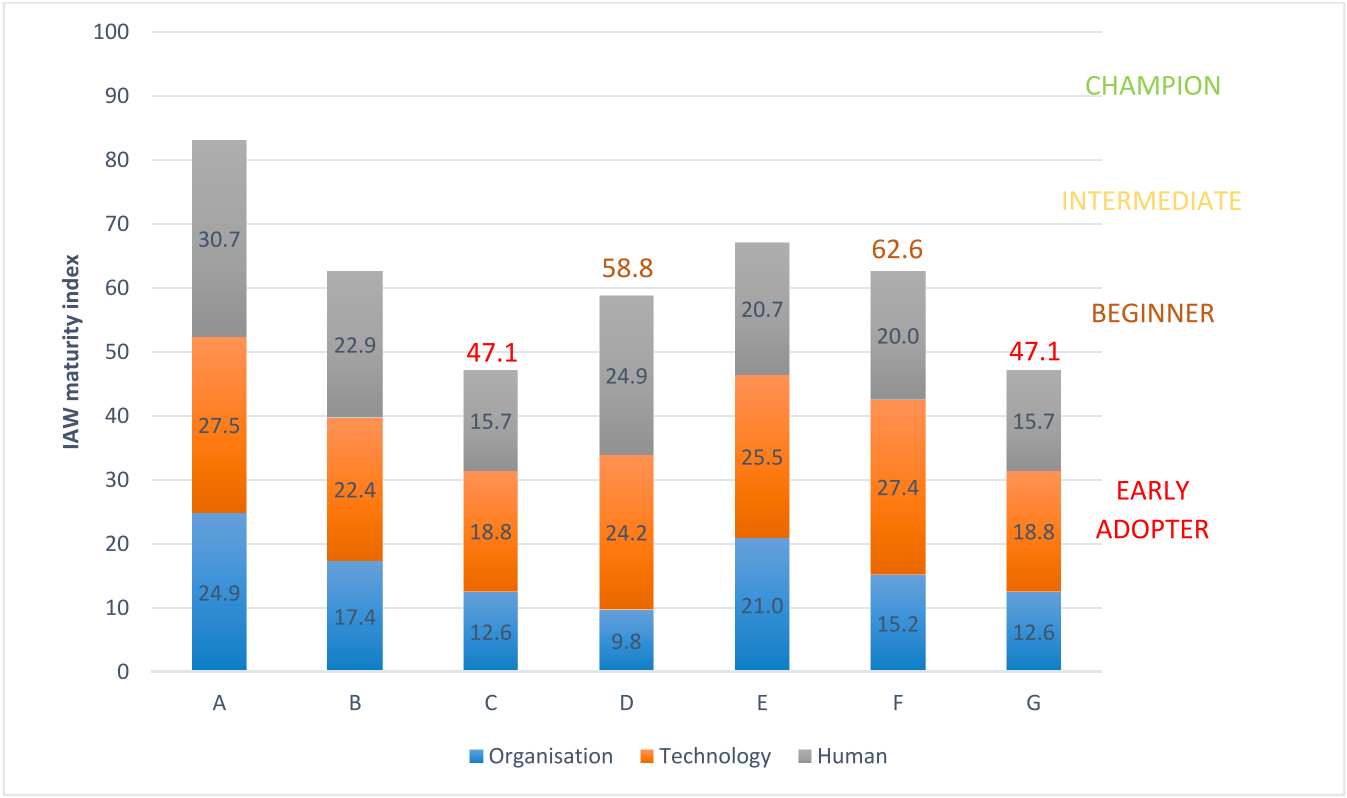

Fig. 2. IAWMI of the companies interviewed.

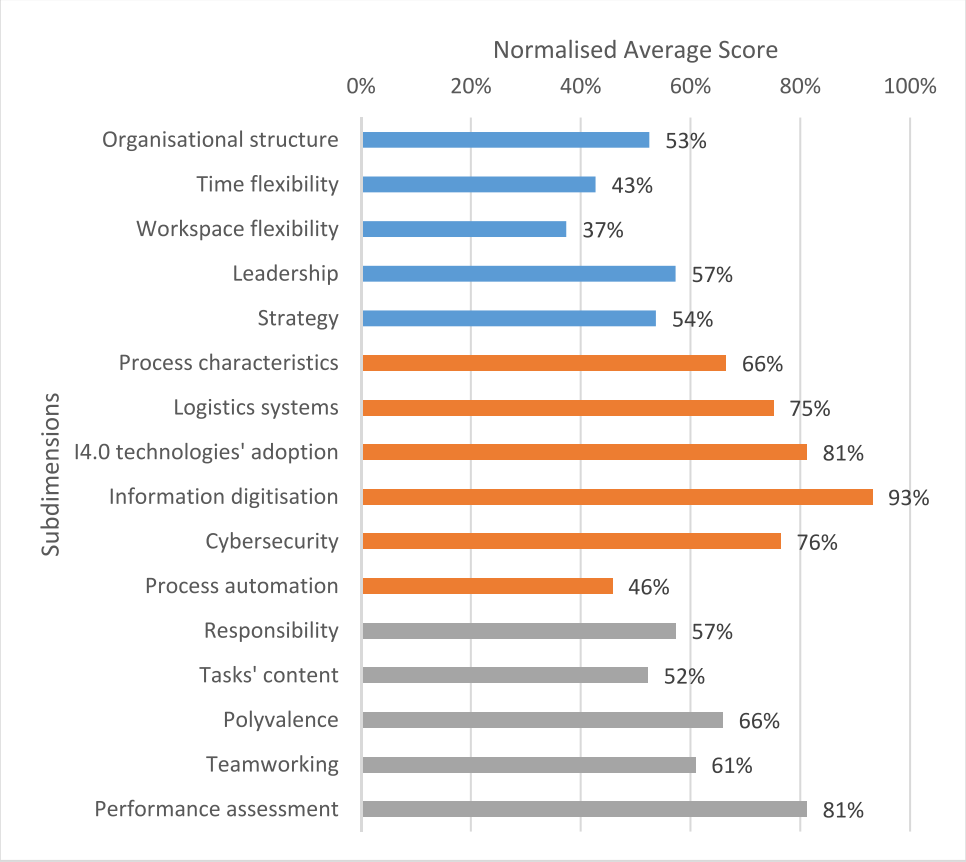

Fig. 3. Normalised Average Score of the subdimensions in the interviewed companies (Blue bars = Organisation subdimensions, Orange bars = Technologies subdimensions, Grey bars = Human subdimensions). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

goal of having a formally vertical but operationally horizontal organization characterized by an open system and a good degree of resilience.

The sub-dimensions that currently appear to be more widespreadly implemented are related to *information digitization*, as in most of the surveyed companies, data and information are all digitized, accessible and shareable from places inside and outside the company thanks to cloud systems. Two other sub-dimensions in which a high level of maturity was assessed are *Polyvalence* and *Team working*.

Fig. 3 depicts the average score of the assessed subdimensions, which have been normalised, considering the maximum score that could be obtained for each. As expected, the more mature dimensions concern the *technology*, while the *organisation* and workers' subdimensions are all in a low/intermediate stage of maturity.

Looking at the results, it has been observed that in some cases companies demonstrated balanced maturity in the three dimensions HTO (such as company A) while some others showed unbalanced situations (such as company D or F, that obtained high score in Technology and very low score in Organization). In our interpretation, these results suggest that achieving higher level of maturity in implementing IAW practices need joint efforts to improve holistically company features ranging from technology and process to organization and HR management. Unbalanced advancement in only one dimension of the HTO model generally prevent from obtaining high maturity levels.

6. Discussion and conclusions

IAW is an example of a change of approach in work management and execution. The term AW is nowadays misused to refer to the possibility of performing from home work tasks that should be done inside the factory. As learned from the phenomenon studied, the term IAW refers to applying agile and flexible working practices that allow employees to work remotely and flexibly in factories. Therefore, they can autonomously manage how much and where to work against greater responsibility for the results achieved individually and by the whole work team.

Consequently, the worker must be provided with all the necessary technological tools to foster remote work, specifically remote communication and sharing of data and information between employees. This concept implies that, in turn, the worker himself must possess the digital skills necessary to use these tools effectively.

This research work answered the two main research questions related to the most relevant dimensions that affect the applicability of AW practices in an industrial context and the methods to measure the maturity of a company in adopting IAW practices. Concerning RQ1, based on a literature review, 19 dimensions was identified and then discussed with industrial stakeholders to identify a final set of 16 dimensions, belonging to three areas, i.e. organisation, technologies and workforce. Further, to answer RQ2, a maturity model to assess the industrial companies maturity in approaching Agile Working methods has been conceptualised and applied to a sample composed by 7 manufacturing companies.

Thanks to the meetings with the companies, it emerged that the proposed IAWMM lends itself well to assessing readiness, especially concerning technology. This factor could help implementing such practices; in fact, technologies are fundamental in facilitating the increase of flexibility and autonomy in the management and execution of work by factory workers. It also emerged that the model succeeds in giving due importance to key dimensions such as spatial and temporal flexibility, job enrichment and enlargement, and production system characteristics, which are fundamental factors for the flexibility of the

work of blue collars. From the discussion with the managers of the various companies, especially with those who then ranked themselves at a high level of maturity, it emerged that the empowerment of employees with regard to results achieved is of significant strategic importance. Therefore, to implement a goal-oriented approach, management must embrace a cultural change based on autonomy and not on controlling the hours spent in the factory. It must be emphasised that not all factory activities can be flexible and that often operators, due to process constraints, do not possess the necessary autonomy in managing their tasks. However, at the department or work team level, it is easier and more immediate to think of greater flexibility. Therefore, from this research it emerged that the job profiles that enjoy or could enjoy, in the near future, good spatial and temporal flexibility are: testers, maintenance workers, installers, quality control operators or groups of operators. in particular, these job profiles are less tied to production processes that require synchronization and imposed cycle times for advancement. Instead, they already perform activities predominantly in teams and with a good degree of self-organization in terms of scheduling the tasks to be performed. They also already take advantage of the potential of some enabling technologies for remoting, as is the case, for example, for installations and after-sales support through Internet communications and, with a desirable increase in the near future, through virtual commissioning. In fact, profiles related to maintenance and after-sales support already possess more advanced skills that will therefore allow for their better flexibility. On the other hand, as far as profiles related to quality control are concerned, for example, what may prove relevant is a better organization of work teams that can allow a good level of time flexibility for workers, without, however, going to decrease the level of service of the quality department towards production systems. This can be pursued for all activities that fall within the scope of quality spot checks and statistical process control analysis. Furthermore, the use of agile working could improve the working conditions of elderly workers: the ageing population requires finding ways to ensure a better working life pattern for elderly workers and agile working could be a useful tool in this direction, providing an improvement in the work-life balance as well. All the aspects analysed should constitute a good starting point for managers interested in implementing IAW strategies in their companies.

Finally, it is essential to emphasise that this research has limitations and future research paths can be envisioned. One limitation is the small number of companies interviewed in the application phase that do not allow to derive from the study a general overview of the maturity level of Italian or European manufacturing companies. To further verify the validity and effectiveness of the model, it should be applicable to a more significant number of companies belonging to different sectors and sizes, also in order to create benchmarks for industrial companies. Another limitation may be to consider a non-exhaustive set of dimensions and sub-dimensions to understand a phenomenon that is undoubtedly very complex. In the future, it will be possible to extend the current set of dimensions and sub-dimensions including broader aspects concerning both innovations in technologies and organisational models. In particular, future research should address a more in-depth exploration of the different AW dimensions, focusing on the peculiar ones characterising each industrial sector and area (e.g., production, assembly, quality, logistics, maintenance) or workforce charactieristics (e.g., age, gender, carreer level, job profile).

In light of these limitations, the interviewed companies agreed that the presented model is valid for assessing the maturity level for applying IAW and raise awareness about the pontentials of applying these practices with tangible benefits to companies, workers and society at large, thus promoting an evolution towards more flexible work organisation models and human resource management strategies.

CRediT authorship contribution statement

Chiara Cimini: Conceptualization, Writing – original draft, Data curation, Formal analysis. **Alexandra Lagorio:** Methodology, Writing – original draft, Formal analysis. **Sergio Cavalieri:** Conceptualization, Writing – review & editing, Validation, Supervision.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

The data that has been used is confidential.

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