

Managing Industry 4.0 Automation For Fair Ethical Business Development: A Single Case Study

Authors:

Emanuele Gabriel Margherita, University of Tuscia, Department of Economics Engineering Society and Organization – DEIM, Via del Paradiso, 47, 01100, Viterbo, Italy - emargherita@unitus.it (corresponding author)

Alessio Maria Braccini, University of Tuscia, Department of Economics Engineering Society and Organization – DEIM, Via del Paradiso, 47, 01100, Viterbo, Italy – abraccini@unitus.it

Abstract

Manufacturing organisations are adopting Industry 4.0 (I40) technologies to automate decision making and operational tasks down the assembly line. Manufacturing organisations can achieve benefits at the level of capital and labour welfare through a more optimised production process, stable employment and enriched duties for workers. Nevertheless, the benefits of I40 adoption produce on the capital could be detrimental for the labour welfare. I40 automation can lead to job disruption, impoverishment of workforce roles and expertise along the production process. There is a lack of studies that explores how organisations adopt I40 technologies to reach a fair balance between capital and labour welfare benefits because management privileges the I40 automation potential over the workforce role in I40 adoption. We address this gap by conducting a single case study of the Italian production branch of an international manufacturing organisation adopting I40 technologies. The results show that organisations achieve a fair balance between capital and labour welfare benefits by deploying I40 technologies with a worker-centric approach. I40 assembly line operates with a sociotechnical interplay between technologies and workers. I40 technologies automate repetitive and dangerous activities, and workers reduce routine work and enrich their duties taking on supervision activities on the assembly line. To this end, workers are trained to acquire digital competencies and maintain a higher level of knowledge of the production activities.

Keywords: industry 4.0, ethical business development, workforce development, industry 4.0 benefits, industry 5.0, fairness

Introduction

Manufacturing organisations are automating assembly lines adopting advanced digital technologies – Internet of Things, robotics, big data analytics, 3D printing – under the push of innovation programmes named Industry 4.0 (I40) (Kagermann, Wolfgang, & Helbig, 2013; Kang et al., 2016). Manufacturing organisations use I40 technologies to innovate, exploit new market opportunities, or defend their competitive position against low-cost producers (L. Li, 2018; Porter & Heppelmann, 2014). In such automation, decision making and operational tasks pass from workers to machines (Kim, 2017; J. Lee, Bagheri, & Kao, 2015). Hence I40 changes the way human labour contributes to value generation on the assembly line (Bonekamp & Sure, 2015; Margherita & Braccini, 2020).

The literature highlights several benefits of I40 that manufacturing organisations can achieve, both at the level of capital and labour welfare (Gupta, Kumar, & Wasan, 2021; Kumar, Singh, & Dwivedi, 2020; Shayganmehr, Kumar, Garza-Reyes, & Moktadir, 2021). I40 adoption supports the business capital development with higher productivity and higher quality products (Fatorachian & Kazemi, 2018; Kang et al.,

2016). I40 technologies also afford reductions for energy savings, better resources usage, reduced downtimes and shorter lead time (Braccini & Margherita, 2019; Ghobakhloo, Fathi, Iranmanesh, Maroufkhani, & Morales, 2021; Tortorella & Fettermann, 2018). I40 supports labour welfare by promoting new managing roles along the assembly line (Romero, Stahre, & Taisch, 2020; Romero et al., 2016). I40 adoption also supports labour welfare by moving workers far from hard-muscular tasks (Erol, Jäger, Hold, Ott, & Sihn, 2016; Shamim, Cang, Yu, & Li, 2016). Finally, I40 technologies may help in reducing performance conflicts between workers and supervisors due to the availability of fine-grained data on operations (Kiel, Muller, Arnold, & Voigt, 2017; D. Li, Fast-Berglund, & Paulin, 2019).

However, the benefits I40 technologies produce on the capital side could be detrimental for the labour welfare (Wang & Siau, 2019). I40 automation may lead to the reduction of job positions as a consequence of the extensive replacement of human labour with machines (Chin, Jiao, & Jawahar, 2019; Frey & Osborne, 2017; Haleem & Javaid, 2019) also for decision-making activities (Bonekamp & Sure, 2015; Nurazwa, Seman, & Shamsuddin, 2019). Even when I40 technologies do not fully replace the workforce, the management can reduce the role of the workforce in assembly lines due to the lack of digital competencies to manage these technologies (Bonekamp & Sure, 2015). Finally I40 adoption may keep workers far from operations reducing their accumulation of knowledge on the transformation process and reducing in turn their performance (Bednar & Welch, 2020; Burton-Jones, 2014).

The rationale of the benefits produced by I40 is the pivotal role that I40 technologies have on the automation of the assembly line. Thus organisations may have an incentive to push automation to seek capital benefits (Wang & Siau, 2019) and face the ethical dilemma of pushing too much towards capital investments damaging labour welfare. To develop their business ethically manufacturing organisations should deploy I40 technologies fairly towards capital and labour (Trentesaux & Caillaud, 2020; Trentesaux & Karnouskos, 2021), seeking a fair balance between extensive automation and labour (Gabriel & Pessel, 2016; Stock & Seliger, 2016). However, current literature exploring I40 technologies adopts a technocentric perspective focusing on performance benefits achievable by the optimized deployment of I40 technologies (Hooker & Kim, 2019; Kang et al., 2016; Wright & Schultz, 2018).

In this paper, we address this gap by conducting an exploratory single case study of the Italian production branch of an international manufacturing organisation that undertook I40 adoption, reaching a fair balance between the benefits of capital and labour welfare. We address the following research question: *"How does a manufacturing organisation adopting Industry 4.0 support a fair capital-labour welfare balance in a fair ethical business development?"*

We contribute to the literature by showing that a fair balance between benefits on capital and labour welfare in I40 adoption is possible. We then illustrate how I40 technologies are deployed for a fair ethical business development, pinpointing the automated activities and the enriched duties of the workforce that compensate for the reduction of their activities. Finally, we show managerial solutions to prepare workers for their novel role.

We structured the paper as follows. First, we describe in the theoretical background the I40 initiative, the concept of fairness in ethical business development, the fair capital-labour welfare development in I40 adoption and its challenges in section 2. Section 3 is devoted to the research design. We describe the case study in section 4, and we portray the fair balance between benefits on capital and labour welfare. In section 5, we discuss our findings against the literature proposing four theoretical propositions and reflecting on implications for research and practice. Finally, we conclude the study in section 6.

2 Theoretical background

In this paper, we explore how organisations can adopt I40 with for a fair balance between capital and labour welfare benefits. In this regard, our paper refers to I40 technologies and their innovation potential for fair

business development in manufacturing organisations. Thus, the current section is divided into three subsections in which we respectively (i) conceptualise the role of I40 technologies for manufacturing organisations, (ii) outline the concept of fair ethical business development, and (iii) elaborate on the role of I40 technologies for a fair capital-labour welfare development.

2.1 Innovating manufacturing with Industry 4.0

The term I40 derives from the German term "Industrie 4.0" and was mentioned in public for the first time at the "Hannover trade fair" in 2011 in Germany (Kagermann et al., 2013). I40 is an industrial plan, developed consequently by all modern manufacturing economies, that promotes the adoption of enabling digital technologies along the assembly line of manufacturing organisation to optimize the production process (Aceto, Persico, & Pescapé, 2020; Dalenogare, Benitez, Yala, & Frank, 2018; L. Li, 2018). I40 programs concern the deployment of advanced enabling digital technologies in assembly lines:

- Internet of Things: it is used to integrate physical objects – such as pieces of machinery or materials – into computer-based systems to collect and communicate data in real-time among systems and humans (de Sousa Jabbour, Jabbour, Foropon, & Filho, 2018; Kang et al., 2016). Internet of Things technologies make use of tags (such as barcodes, QR codes or RFIDs), sensors and controllers to collect data from machinery.
- Robotics: a heterogeneous set of automatic or semi-automatic machinery that can perform tasks without human supervision or collaborate with human tasks (Haleem & Javaid, 2019).
- Cloud manufacturing: a virtual network that connects different supply chain actors affording for the storage and exchange of large volumes of data and on resources sharing on-demand through an internet-connected digital platform (Xu, Xu, & Li, 2018). Cloud manufacturing offers the assembly line actors low-cost high scalable, and high-performing solutions (Aceto et al., 2020).
- Additive manufacturing: a set of technologies that use 3D computer systems to design and print objects, adding layers of materials rather than removing materials from a solid block (Braccini & Margherita, 2019; Haleem & Javaid, 2019). Additive manufacturing affords fast prototyping, production, and customisation of products.

The integration of these technologies on assembly lines forms cyber-physical systems, i.e. fully automated pieces of machinery that can be programmed with software to transform raw materials into finished products, and that produce a digital trace of all their operations (Kagermann et al., 2013; Kim, 2017). Such cyber-physical systems afford manufacturing organisations to automate operational and decision-making tasks – such as stopping the production for preventing errors or for performing maintenance tasks – on assembly lines that can be fully autonomous (Kim, 2017; J. Lee et al., 2015). The data produced by such cyber-physical systems can facilitate integration among assembly line actors (Kagermann et al., 2013; Müller, Buliga, & Voigt, 2018) and can be used to continuously improve the assembly lines. Thus, I40 assembly lines are horizontally and vertically integrated, allowing for virtual production and mass customization (Haleem & Javaid, 2019), and easy collaboration among partners within a supply chain (Kagermann et al., 2013; Müller, Buliga, & Voigt, 2018).

2.2 Fairness in Ethical Business Development

Ethical business development combines the concept of "business development" and "business ethics". Business development refers to the organisational practices on the economic system, and it represents the organizational attitude to create value in the production and distribution of goods and services (Kiel et al., 2017). In profit-oriented manufacturing organisations, such practices aim to economic growth and increase the organisation's profits to support the business capital (Wang & Siau, 2019). Business ethics combines the concept of ethics, i.e. "the strive for the good life, with oneself and others, in fair institutions" (Ricoeur, 1990), with that of business development. For our paper, we consider ethical business development that

encompasses the needs of the different actors involved in business organisations (Donaldson & Dunfee, 1994).

Given that the ethical approach towards capital and labour welfare depend on the socio-economic context in which the decision is taken (Morahan, 2015), in this paper we address the perspective of a fair ethical business development, i.e. investment decisions that seek a fair balance between capital development and labour welfare (Morahan, 2015; Trentesaux & Karnouskos, 2021). An organisation acts fairly towards labour welfare by promoting stable employment, job enrichment, workers satisfaction, career development, and well-being (Bowie, 1998; Michaelson, Pratt, Grant, & Dunn, 2014). Therefore, we consider fair the ethical business development that aims at balancing the benefits of capital and labour welfare without detriment to none of them, promoting capital benefits and maintaining stable and satisficing work conditions (Michaelson et al., 2014; Morahan, 2015).

2.2.1 Fair capital-labour welfare development in Industry 4.0

The extant literature reports that I40 adoption delivers benefits on capital and labour welfare (see Figure 1).

I40 adoption supports the business capital increasing efficacy and effectiveness of processes through automation (Fatorachian & Kazemi, 2018; Haleem & Javaid, 2019). I40 technologies can be implemented down a lean production in order to reduce the lead time of operations and maintain constant workflow (Tortorella & Fettermann, 2018).

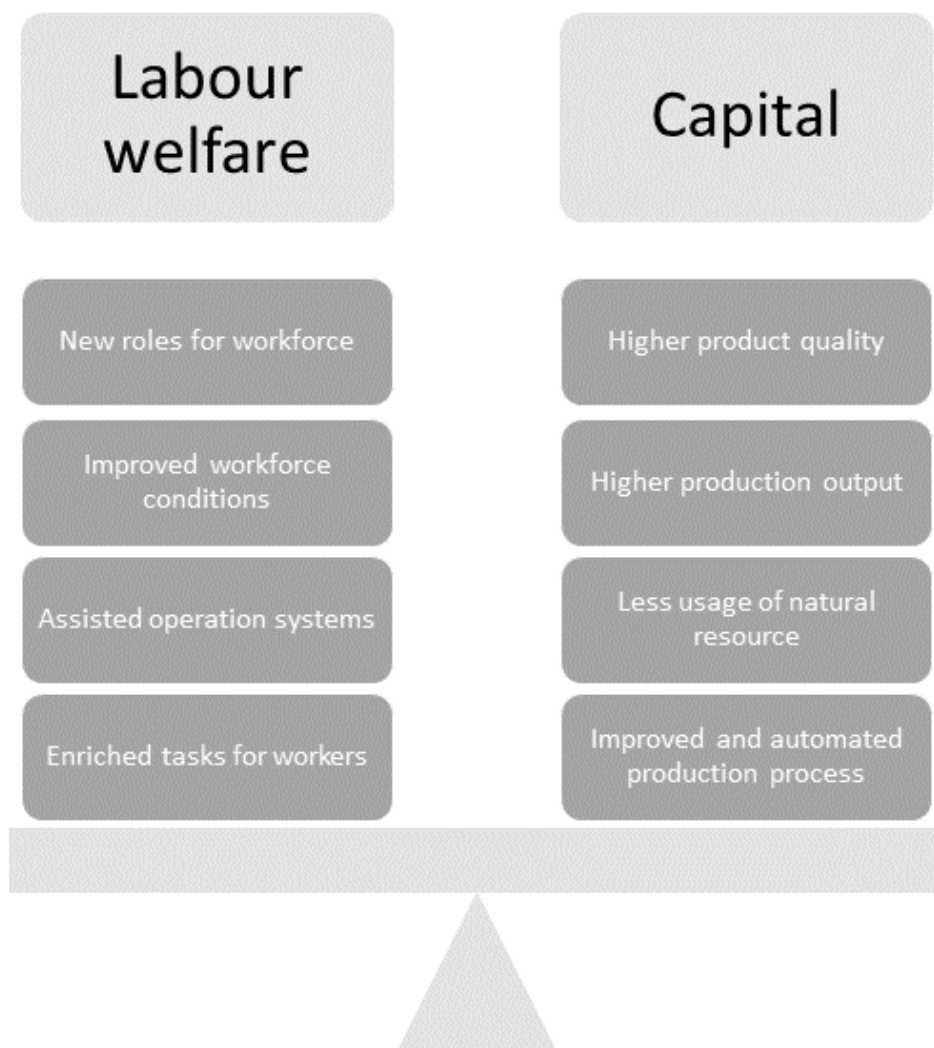


Figure 1 Fair Ethical Business Development of Industry 4.0 adoption

I40 adoption increases output quantity, product quality and reduces natural resources because the production experiences less downtime and more precise operations (Braccini & Margherita, 2019; Ghobakhloo et al., 2021). Also, the integration of data improves the effectiveness of managers and control activities, leading to resource savings (Margherita & Braccini, 2020). I40 adoption supports labour welfare by creating new job roles. Novel activities are required to manage I40 technologies along the assembly line that can be addressed by the requalification of the workforce and hiring new ones (Romero et al., 2020, 2016). There is also a need for project managers who can deal with I40 projects and work in unit related to these technologies and a more complex IT unit to develop and handle I40 technologies (Margherita & Braccini, 2020; Sony & Naik, 2019). Moreover, I40 adoption improves work conditions by automating hard-muscular and dangerous activities (Gabriel & Pessel, 2016; Sony & Naik, 2019; Xu, Xu, & Li, 2018). Still, the way of producing in an I40 assembly line may stimulate the workforce creativity as workers can contribute to the continuous optimisation of the production process and development of new ideas for improved products, process, and services (Erol et al., 2016; Shamim et al., 2016). The management and decisions related to job performance are transparent because they are based on fine-grained operations data (Kiel et al., 2017). Workers can use the human-computer interface of I40 technologies to communicate with their colleagues, enabling knowledge sharing that sustain knowledge operations within the organisation (D. Li et al., 2019).

2.2.2 Challenges in achieving a fair labour-capital development in Industry 4.0

To date, the extant literature devoted to exploring I40 adoption follows a technocentric perspective (Kang et al., 2016). This perspective privileges the role of I40 technologies over the workforce in the assembly line and emphasizes only the benefits on the capital side. We summarize the challenges that organisation encounter in a fair ethical business development through I40 adoption to reach a fair balance between capital-labour welfare benefits in Table 1.

By extending the automation to decision-making activities, I40 potentially leads to job disruption, especially for low-skilled workers (Kang et al., 2016; Wright & Schultz, 2018). The manufacturing industry has already experienced the disappearance of routinary jobs due to technology (Frey & Osborne, 2017). I40 continues this erosion, potentially automating the entire production process (Kang et al., 2016; Wright & Schultz, 2018). Furthermore, I40 challenges both blue and white-collar jobs since I40 automates both operational and decision-making activities (Bonekamp & Sure, 2015; Nurazwa et al., 2019). The workforce may have fewer opportunities to undertake a career and remain stably employed in a manufacturing organisation (Chin et al., 2019; Sony, 2020). The reduction of the staff cost – one of the higher organisational expense in manufacturing – corresponds to capital benefits (Sony, 2020; Wang & Siau, 2019).

Traditional manufacturing workers only possess operational competencies to assemble products (Margherita & Bua, 2021) not adequate for working with I40 technologies (Bonekamp & Sure, 2015; Nurazwa et al., 2019). The reskilling of these workers have a huge cost, and it is risky since there is a significant distance between traditional and I40 digital competencies (Sony, 2020). Even after training, workers can cause recurring maintenance issues in the I40 assembly line, leading to higher costs (Prause, Atari, Prause, & Atari, 2017). Replacing these workers is challenging as well since I40 skilled workers are scarce and expensive on the job market. The workforce replacement also leads to a loss of know-how and expertise in manufacturing organisations (Margherita & Braccini, 2020; Sony, 2020). Therefore, the organisation can opt to impoverish the workforce role and leverage on extensive I40 automation to sustain productivity and save costs for mismanagement and workforce development (Bonekamp & Sure, 2015; Nurazwa et al., 2019).

I40 adoption can also lead to low performance of workers along the assembly line because it impedes workers' knowledge accumulation (Burton-Jones, 2014; Malone, Laubacher, & Johns, 2011; Zuboff, 1992). Thus, workers no longer have proper knowledge of operations to work efficiently (Bednar & Welch, 2020). They are involved only in a small segment of the production process and lack visibility of the whole system (Mehri, 2006).

These challenges open the issue of fairness in ethical business development as the capital benefits can be realised with worse workforce conditions (Wang & Siau, 2019). Acting fairly towards workers is not an obligation for an organisation, neither reaching a fair balance between capital and labour benefit. These unfair practices presented in the ethical dilemma are not sufficiently prevented by the law (Morahan, 2015) and I40 industrial plans. These plans provide funds to purchase I40 technologies without considering any kind of social protection for workers (Sony, 2020). Therefore, profit organisations are not incentivised to act fairly towards workers. Instead, they are incentivised to deviate and support capital at the expense of labour (Wang & Siau, 2019). Thus, organisations wanting to achieve a fair balance between capital-labour welfare benefits through I40 adoption should overpass such challenges and find a fair division between activities to automate and leave to the workers.

Challenge	Reference	Description
Reduction of human activities in the production systems	(Chin et al., 2019; Frey & Osborne, 2017; Haleem & Javaid, 2019; Kang et al., 2016)	The automation produced by I40 technologies improves the production process and disrupts labour, replacing workers with machines, both for operational and decision-making activities. Workers no longer play a crucial role in the production system, and their lay-off allows the organisations to reduce staff cost.
Marginal role of workers due to lack of competencies for the maintenance of I40 technologies	(Bonekamp & Sure, 2015; Margherita & Bua, 2021; Nurazwa et al., 2019; Prause et al., 2017)	Traditional manufacturing workers do not possess the competencies to deal with I40 systems. Requalify workers or hiring new ones is a challenging and costly strategy. Thus, organisations opt to adopt a more automated I40 application and reduce workforce role to support capital by improving production and reducing workforce development costs.
Reduction of knowledge of production operations	(Bednar & Welch, 2020; Burton-Jones, 2014; Mehri, 2006; Zuboff, 1992)	I40 adoption improves the production process and leads to the workforce's low performance. The automation of production core activities impedes workers from acquiring the proper knowledge to conduct effective operations and reduces the potential for creativity and innovation.

Table 1 Challenges to achieving fair capital-labour welfare benefits in Industry 4.0

3 Research Design

We conducted a single case study analysis of the production unit of the Italian branch of an International electrotechnical organisation that produces electrical switches (ELECTRIC a fantasy name). Given the nature of the research and limited body of knowledge of how I40 adoption supports the organisation to a fair ethical business development that reaches a fair balance between capital and labour welfare benefits. The case study approach is the most suitable methodology for the empirical investigation. The case study is appropriate when investigating a poorly researched phenomenon and where data required for formulating hypotheses have not yet been obtained (Eisenhardt, 1989; Yin, 2018). Exploratory case studies typically address how and why questions (Yin, 2018) concerning the dynamics present within a particularly contextual setting to develop initial understandings (Eisenhardt, 1989; Yin, 2018). The case study is well-accepted in the IS literature when the studies discuss the societal transformation enabled by technologies (Benbasat, Goldstein, & Mead, 1987; Braccini & Margherita, 2019; Seidel, Recker, & vom Brock, 2013). Specifically, the single case study is appropriate if the case under scrutiny is critical, extreme, unique and revelatory (Dube & Pare, 2003).

The single case study claims for analytic generalization of the phenomenon that allows for the development of theoretical propositions that can be statistically tested in future studies (Yin, 2018).

3.1 Case Selection

We consider the case of ELECTRIC as a revelatory case study (Dubé & Paré, 2003; Yin, 2018) for four reasons:

1. ELECTRIC is the first mover in its competitive domain to undertake a fair ethical business development of I40 technologies in 2017. In addition, the organisation was ranked among the best employers in Italy by a distinguished national newspaper and received a prize for corporate social responsibility.
2. In 2019, ELECTRIC supported capital by doubling production. At the same time, it supports labour welfare by defending employment levels and foster enriched work and better work conditions. This evidence confirmed that the organisation reached a fair balance between the benefits of capital and labour welfare. Thus, it provided a suitable context for the study.
3. The production process of ELECTRIC is labour-intensive, and the organisation's management is very attentive to sustain labour welfare. The organisation has implemented ISO 9001, ISO 45001, and the certifications OHSAS 18001 and ISO 45001 to manage safety within the plant. It has a long-standing commitment to community engagement by providing impactful support for community-building initiatives across three pillars: education, diversity and inclusion, and care in the community. Also, the organisation adopted many pieces of I40 technologies in a fair manner in various units. Therefore, this context is prominent to explore how the management addresses the challenges to reach a fair balance between the benefits of capital and labour welfare.
4. ELECTRIC is the leader of a manufacturing cluster for the deployment of I40 plants in Italy. ELECTRIC serves as a model for studying pilot projects that other organisations eventually adopt in the cluster in a fair manner.

3.2 Data collection

We followed Yin's principles (2018) concerning data collection. One of the researchers spent two full days in November 2019 visiting the organisation invited by the public relation officer. He collected 17 semi-structured interviews of key informants of the fair ethical business development of I40 adoption. Such key informants include both the management and the workers (4 women and 13 men). He first approached the public relation officer of the company to introduce the research objective and to receive a first overview of the I40 adoption in the organization. The public relation officer introduced him to the management who participated in the fair ethical business development of I40 adoption as members of the steering committee. Also, the management put the researcher in contact with a worker supervisor from the assembly line involved in the I40 adoption. Separately he also reached out and interviewed three more workers - one worker supervisor and two workers - involved in the I40 adoption and operating in the assembly line before and after the I40 adoption. We decided to interview the management and the workers to have a more transparent representation of I40 adoption and its fair ethical business development. It is also a valid strategy because the voices of the two groups often diverged on themes related to how work conditions changed after the technology adoption and the consequences of technology automation on the assembly line workforce (Sawyer & Jarrahi, 2014). In Table 2, we illustrate the details of the interviewees and their role during the I40 adoption. The interviews were conducted face-to-face, recorded, and transcribed. The interviews in total lasted for about eight hours, with varying lengths (from 15 to 60 minutes each). The researcher also conducted observations and took field notes on the traditional assembly line, the I40 assembly line, the operation of smart machines and control systems and the activities performed by workers.

Role	Interviewees	Activities played in the I40 adoption
COO	1	He managed the entire I40 project.
CPO	1	He managed cobot adoption.
Industrial engineer	2	They managed the development and adoption of I40 technologies, especially the augmented reality application.

Role	Interviewees	Activities played in the I40 adoption
Mechanical maintenance	2	They managed the development and adoption of cobots movements, its vision system and smart sensor system.
Quality manager	1	He managed data of the I40 assembly line.
Informatics Engineer	3	They managed the development and adoption of the advanced manufacturing enterprise systems and data analytics and tracking system.
Public Relation officer	1	She supports the management of the entire I40 project.
Supply Chain/Operation Engineer	1	She managed the development and adoption of the I40 operation, logistics and supply chain system.
Supervisor worker of the I40 assembly line	2	They are experienced human resources involved in I40 adoption and working in the assembly line before and after the I40 adoption.
Workers of the I40 assembly line	2	Workers involved in I40 adoption. They perform daily tasks on the assembly line before and after the I40 adoption.
Products engineer	1	He managed the industrialisations on the I40 assembly line of new products.

Table 2 List of interviewees and their roles during the Industry 4.0 adoption

For conducting the interviews, we used a track covering the different areas mentioned by the I40 literature. During the interviews, we slightly adjusted the track to encompass the different points of view of each role related to the fair ethical business development of I40 adoption (Yin, 2018). The interview track is showed in Table 3.

Interviewees	Questions
Management	Organizational dimensions: employee number, years of activity, and produced goods Type and extensions of I40 technologies Details of the traditional production process (workforce and technology operations) The sequence of actions performed during the adoption of I40 technologies Workforce issues to operate in the I40 production line The management of workers to prepare them for the I40 assembly line Details of the I40 production process (workforce and technology operations) Benefits of the labour welfare after I40 adoption Benefits on the capital after I40 adoption The management of I40 automation in the I40 assembly line The management of knowledge of operations of workers in the I40 assembly line
Workers	Type and nature of the work performed in the organization Experience and details of the traditional production process The involvement in the I40 adoption process Experience and details of the I40 production Benefits of the labour welfare after I40 adoption Benefits of the capital after I40 adoption Personal awareness of the benefits of the adoption of I40 technologies Benefits of I40 automation and technologies The management of knowledge of operations of workers in the I40 assembly line

Table 3 Interview Track

We triangulated secondary data sources to increase the reliability and validity of data (Denzin, 2006). As secondary data sources, we used the official balance sustainability statements of ELECTRIC, the official balance statement of 2018, and distinguished national newspapers articles reporting the outcome of the ethical business development of ELECTRIC. We include the official balance sustainability statement since we

found a section dedicated to the organisation's sustainability, which embraces social themes, including safety and social indicators, as the number of employees and turnover is strictly related to our study. We use the chamber of commerce company registration of ELECTRIC to acquire official data on the employment level of the production unit.

3.3 Data Analysis

For the data analysis, we combined all the interview transcriptions and the secondary data sources in a single research database. In total, we coded about 19,000 words from interviews transcriptions and field notes, and 180.620 words from secondary data, 5.420 words from web articles and 175.200 words from official balance statements.

We conducted data analysis using CAQDAS as a supporting tool. We made use of first, and second-level codes. The first coding represents first-level concepts that adhere faithfully to informant terms. With second-level coding, we aggregate these first-level concepts in categories by distinguishing similarities and differences among them (Corbin & Strauss, 2015). We analysed the data to identify how the management reaches a fair balance between capital and labour welfare benefits. The research follows an inductive approach following qualitative inquiry principles to maintain methodological rigour (Corbin & Strauss, 2015). Only one of the two authors coded the materials in the CAQDAS using codes emerging from the words of interviewees, adding codes and categories during the analysis. Both authors regularly discussed the results of the coding together. The single coder iteratively coded the materials in several iterations, followed by discussion sessions. The coding stopped when both authors agreed on the results of the coding.

Researchers accomplished the findings after three iteration rounds adopting a two-fold saturation criterion: (i) all the data sources could be coded with the set coding structure, and (ii) the research team agreed on the result of the coding. When there were conflicts in the accounts of the participant, we organised follow up phone calls for clarifications. We also increase the reliability of our analysis by presenting our findings to one key informant – one worker – that confirmed our results (Yin, 2018). Appendix 1 shows the coding data structure used in our analysis and the exemplary statements.

4 The Case of ELECTRIC

ELECTRIC is one production unit located in Italy of an International electrotechnical organisation producing electrical switches through both automated and manual assembly lines. ELECTRIC, founded in 1979, currently employs about 850 employees, of which 80% are blue-collar and 20% white collar. ELECTRIC is one of the organisation leaders of the market. This market has a total value of US\$ 7.6 Billion in 2019¹. ELECTRIC is also a leader of an Italian manufacturing cluster for the development of I40 applications.

Before the I40 adoption, ELECTRIC uses a traditional manual assembly line structured in islands and is composed of 16 workstations. The process consists of the pre-assembly phase and assembly phase. Each worker conducts all the operations of pre-assembly or assembly phases on a workstation manually with the help of traditional technologies. Workers conduct the pre-assembly phase on five workstations. One worker is in charge of unloading components from boxes. Four workers conduct all the operations to build components for the assembly phase. The assembly phase is performed on 11 workstations. Each of the eleven workers conducts all the operations to conclude the switch assembly and customisation by employing different utensils, such as soldering machines and performing electricity and temperature quality tests on products. All the workers can conduct all the operations of the two phases and follow preparation lists created according to customers' orders.

¹ Circuit Breaker Market: Global Industry Trends, Share, Size, Growth, Opportunity and Forecast 2020-2025
<https://www.imarcgroup.com/circuit-breaker-market> retrieved: 10/08/2020

The logistic is also manual. Workers place the finished products in packages marking the production line batch, and then a logistics worker moves the products to the warehouse by forklifts. When workers find problems with machines, they call the maintenance. When the customer claims a faulty product, the organisation provides after-sales assistance, and workers detect the production issues and fix them.

The traditional assembly line lacks accurate information on output and time. These pieces of data are self-reported by workers that fill in excel files at the end of their shifts. The same self-reporting mechanism is in use also for maintenance reports. The data are eventually used for compiling production statistics. The lack of precision in information reporting creates frequent and recurring coordinating issues between production, logistics, and maintenance. The maintenance unit is not punctual to fix the mechanical issues requesting interruptions of the production flow. Packages are lost during the handling between the production unit and the logistics unit. Moreover, in the pre-assembly phase, several production issues occur due to the repetitiveness of operations. These issues force workers to de-assembly the parts and assembly them again. The operations during the pre-assembly phase generate microplastics that can be inhaled by workers and can be dangerous for their health.

4.1 Innovating the assembly line

In 2017, the management decides to innovate the traditional assembly line by creating a new line with I40 technologies to improve production efficiency, maintain stable employment and improve the workforce conditions. The new line sides the old one that remains in business. Due to the early stage of I40 applications, the management adopts a participatory approach that involves the workforce identifying proper technologies to improve the production and address workforce issues along the assembly line. To this end, they launch a survey for workers seeking to receive their advice. The management eventually decides to adopt a set of I40 technologies (see Table 4), following the survey results.

Industry 4.0 Technology	Description
Semi-automatic conveyor belt with smart sensors	The semi-automatic conveyor belt employs shelves to move semi-finished products along the assembly line which are equipped with proximity sensors to avoid hits. The semi-automatic conveyor belt employs accelerometer sensors to detect mechanical issues of the assembly line. The traceability system collects the data they produce
Robotics	Autonomous or collaborative devices capable of performing specific tasks. Robots can be fully automated and self-moving machines that can manage material picking and handle inside a warehouse, or programmable collaborative robots (cobots) which can perform desired manipulation tasks
Augmented Reality Application	A tablet-based application that exploits augmented reality to guide workers for machine maintenance operations. The worker can point the tablet at part of the machine with a problem. The application will provide visual instructions (pictures, arrows, texts) to guide workers by fixing the mechanical issue. The application also contains a digital copy of all the maintenance procedures of all machines.
Traceability system	Set of integrated systems that use mobile devices, barcode scanners, QR-code scanners, and image recognition to trace work and materials flow on the assembly line. The system can be both automatic or manually operated by workers using manual barcode scanners. The system allows workers to point out human errors that contribute to a work incident.
Data analytics	Set of integrated systems that provide visual and real-time feedback information on workers on the assembly line. The feedback can be referred to costs or time benchmarks or operational instructions on the assembly tasks to perform on the component, product, or by-product.

Industry 4.0 Technology	Description
Manufacturing Enterprise Systems (MES)	This system integrates inbound, production and logistic units. It is integrated with the corporate ERP for collecting customer orders and with the traceability system and augmented reality application to provide statistics

Table 4 Industry 4.0 technologies Description

Based on the survey result, more competent workers in I40 technologies continue to be involved during the adoption process. They are involved in focus groups for the deployment of these technologies as representative of workers' voice. Each piece of technology is developed and adopted by different projects. The management purchases both cobots, smart sensors and automated forklifts. The maintenance unit develops smart sensor systems for semi-automatic conveyor belts and programs the movements of cobots that are peculiar for assembly line operations. The unit programmes the cobot to automate the most repetitive and dangerous pre-assembly activities. The logistics unit, supported by engineers of the operation unit, programmes the automated forklifts to conduct the repetitive trip from the warehouse and the assembly line. The industrial engineering unit cooperates with a technology developer for the AR application. The IT department develops the advanced MES, data analytics and the tracking system, integrating the data of the different technologies with granularity at the level of production steps.

The technology adoption is incremental. The management discusses the innovation plan with all the workers declaring to maintain a stable employment level and explain the production line redesign. Thus, they comprehend how their way of working changes. The workforce reaction is initially adverse as cobots, and automated forklifts completely disrupt some roles. The feedback turns positive when they experience simpler, less repetitive and safer tasks thanks to the I40 technologies. The management provides vocational courses for the workforce to acquire proper competence to operate I40 technologies and autonomously fix potential assembly line errors. During the adoption process, training per year of the workforce passes from 12 hours to 16 hours on average and includes both trainings on the job and mentorship.

4.2 The Industry 4.0 assembly line

The innovative assembly line is semi-automatic and works with a strong interplay between I40 technologies and workers. The I40 assembly line follows lean principles that allow workers to organise the production in a team and help each other reach daily production and reduce workload. The production process starts with MES retrieving orders from the corporate ERP. TV screens along with the assembly line display orders with real-time performance statistics visible to all workers. Each worker conducts only a small part of the pre-assembly phase or assembly phase activities in the entire working turn. Product components are placed on semi-automatic conveyor belts that connect each workstation. In the pre-assembly phase, workers unload components and conduct part of the pre-assembly phase. Thanks to the I40 technologies, one human workstation of the pre-assembly phase disappears with the previous tasks replaced by a cobot workstation. The cobot is in charge of conducting the repetitive activities of the pre-assembly steps of the switches. Moreover, the worker that no longer has the workstation supervises the cobot and help colleagues to maintain constant workflow. Cobot needs to be started and stopped and needs manual intervention in case of failure.

The assembly phase remains manual. Workers finalise the product assemble and conduct the remaining customisation steps. Moreover, each worker performs quality control of the assembly of the previous worker before starting her assembly activities. The components on the assembly line are tagged with barcodes tracked by the traceability system that automatically measures the time spent for each phase. In case of defects, one worker manually reworks the product on a separate island. Workers are also in charge of using the traceability system to provide feedback to management to improve their safety along the line pointing out human errors and how to address them.

The workers on the I40 assembly line address simple mechanical issues of the machinery. They fix these issues in autonomy with AR application assistance, which provides them visual step-by-step instructions. For more complicated issues, the workers call the maintenance unit. At the end of each maintenance, the AR application automatically sends a report where workers can add further comments. This data is acquired by the MES and used for statistics on maintenance.

The finished products are moved to the logistic unit through an automated forklift controlled by the logistic worker who previously drove the forklift.

The traditional assembly line remains in business, structured in islands, to support the I40 assembly line for customer assistance activities where workers repair defective products, and produce some batches of electrical switches that help the I40 assembly line reach the daily production goal. The workers are rotated along the I40 assembly line and interchanged daily the I40 and the traditional assembly line to mitigate the negative effect of repetitions and maintain a high level of knowledge operations. Moreover, how the MES schedule the sequence of products minimises the repetitiveness. Periodically all workers receive training on the latest updates of the I40 technologies.

4.3 Outcomes of Industry 4.0 adoption

I40 innovation produces several outcomes for the business capital. After the I40 adoption, the plant of ELECTRIC reaches a turnover of 550€ million. The lead time of each operation is shorter than before, passing from 40 to 20 seconds on average. Consequently, the production doubles, passing from an average of 400 to 800 switches produced daily. Thus, I40 adoption contributes to increasing the output quantity by 20%, shifting the production from 2,5 million to 3 million electrical switches. The automation of the pre-assembly phase prevents all the common assembly mistakes of the workers. Thus, the defect rate is also reduced to the point that management sets a quality goal of 250 defect pieces per million of produced switches.

As a result of the data collected on the performance of the assembly line, ELECTRIC reduces the cost for energy and prevent common mechanical issues on cylinders of the conveyor belt that may cost 1500€ each in electricity per year. Similarly, the smart sensors allow verifying whether a maintenance intervention on the conveyor belt was successful by comparing performance data before and after the interventions. Thus, I40 adoption, in conjunction with an electrical distribution control system, contributes to reducing the plant's energy consumption by 30%. The combined use of the MES and the AR applications sharply reduces paper consumption because they digitalise machine instruction and the paper-based system to manage the line.

The coordination among the units is also improved. The maintenance workers reduce intervention time from 20 minutes to 9 minutes on average. Through the reports produced by the data analytics system, the management can set challenging quality goals – the threshold of faulty products, daily production quantity – to improve the production and monitor the progress to reach them.

4.4 Achieving a fair balance between capital and labour welfare benefits

Figure 2 summarises the actions that the management employs to address the challenges to reach a fair balance of capital-labour welfare benefits. The I40 adoption transforms the traditional assembly line and adds a semi-automatic assembly line where a cobot workstation replaces one human workstation. Automated forklifts no longer require drivers. Analogously, the maintenance workforce experiences a reduction of routine maintenance activities due to the synergy between workforce and AR application. The management addresses the potential conflict between automation and labour welfare involving the workforce since the beginning of the I40 innovation and increasing their duties. They involve workers in the selection of I40 technologies in order to spot those technologies that can automate the most repetitive and unsafe activities of workers. Also, several workers see their tasks enriched. The maintenance workers are in charge of scouting new I40 technologies and supporting the development of the ones in use.

The logistic workers programme and manage the automated forklifts rather than driving them. The assembly line workers supervise cobots, block and restart them, maintaining constant the production process. Their tasks are enriched with simple maintenance, quality control and assurance activities on the work of their colleagues. In addition, workers can increase their safety by providing feedback to the management to improve their operations.

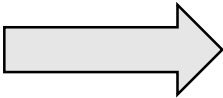
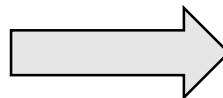
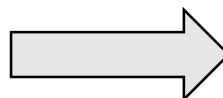
Challenges to achieving fair capital-labour welfare in Industry 4.0		Management actions
Lack of competencies for managing I40 technologies		• Vocational training for the workforce • Training-on-the-job for workforce • Mentorship for workforce • Easy-to-use I40 technologies
Reduction of knowledge of the production process		• Easier production activities • Interchanging workforce between traditional and I40 assembly line • Workers perform cobots activities when cobots are offline • Fast job rotation for workforce along the assembly line • Teamwork facilitates knowledge build-up • I40 technologies support actions to increase knowledge of the production process
Reduction of human activities		• Increasing duties for the workforce of the assembly line • Workforce performs novel creative activities • I40 technologies automate only repetitive activities • Increasing task autonomy for workers

Figure 2 Managerial actions to address challenges to achieving fair capital-labour welfare in Industry 4.0

Workers increase autonomy in operations. They can manage the activities they perform helping each other's – particularly to speed up underperforming lines – and to take these decisions, they are supported by screens showing the daily production trend in comparison with the target set for the day. Management also fosters a safer workplace giving extra compensation and recognition to workers of assembly line who maintain a more organised workplace.

The redesign of the I40 assembly line increases the safety and health of the workplace with a resulting reduction of job accidents. After I40 adoption, there are no employee work-related fatalities. Furthermore, workstations are more spacious and ergonomic. Workers sit distant from the cobots that, by assembling the products, produce microplastics that are no longer inhaled by the workforce.

During the adoption, the workforce expresses concern regarding knowledge reduction on how to assemble the products. Also, how ELECTRIC trains workers to perform the assembly activities privileges the human production steps neglecting the assembly phase performed by cobot. Workers also have difficulties in addressing assembly issues of finished products or when faulty product come back to the firm. The management addresses the concern with a frequent rotation of jobs along the I40 assembly line. Thus, workers perform various assembly activities, increasing the level of knowledge of the production phases and reducing the repetitiveness of assembly activities. Moreover, cobots need human support for loading and unloading operations, and the workers themselves manage the cobots. Finally, when cobots have difficulties in assembling components (due to different shapes or weight of switch components), the workers perform the task in the place of the cobot.

Furthermore, since the traditional assembly line is still in place, the workers are interchanged between the two lines. The work on the manual line helps workers increase their knowledge on the assembly of the entire switch and fix faulty products.

The I40 assembly line strengthens the teamwork among workers: they now assist each other to improve their knowledge of the production process. Since each worker acts as a quality controller against the work of her colleague, the workforce develops analytical skills to potentially fix faulty assembly activities and helping colleagues to perform the activities better.

The work on the I40 assembly line is more straightforward than before, and this allows fast integration of apprentice workers who experienced fewer challenges to acquire the proper knowledge to work along the line.

Through the reports produced by the traceability system, managers identify workers regularly performing below standards and discuss with them countermeasures to improve the performance, including the possibility of attending tailor-made vocational courses, training, or discussing the pace of the work on the process. Workers can also use the technology to point out improvement of operations to prevent potentially work incidents. Still, a maintenance worker can verify whether upkeep along the assembly line is successful through the data analysis of smart sensors.

Finally, the workforce expresses concern about the lack of digital competencies for working with I40 technologies. The management addresses this problem, developing a lifelong learning path for the assembly line workforce. During the I40 adoption, workers attend vocational courses to learn how to use each I40 technology. For robotics, smart sensors, vocational training involves working with these technologies, managing their operations, and addressing potentially mechanical issues, particularly for the cobots. For I40 technologies with a human-computer interface, the courses involve using the embedded systems and their functionalities and addressing potential issues. In addition, the vocational course for the use of AR application also helps workers acquire maintenance competencies with the I40 technologies because they try the application to address mechanical issues of machinery. Then during operations, each worker goes through a period of training on the job and can count on mentorship from skilled workers if the former feels she remain unfamiliar with I40 technologies. Periodically all workers receive training on the new updates of the I40 technologies.

Finally, the number of employees of ELECTRIC grows after the I40 adoption. The last balance sheet of 2018 of ELECTRIC states that the organisation has 858 employees. According to the CPO of the organisation, the workforce number grows about 100 units compared to the employment level of seven years ago. Adding to this, in the following three years (2020-2022), they recruit 122 apprentices, 90 of whom are already recruited in 2020.

5 Discussion

The extant literature reveals a lack of studies exploring how I40 adoption helps an organisation undertake a fair ethical business development between capital and labour welfare benefits (Sony, 2020; Trentesaux & Caillaud, 2020). Because I40 adoption follows a technocentric approach that privileges the automation of I40 technologies over the workers that can be replaced (Kang et al., 2016).

We argue that a worker-centric approach of I40 adoption unveils a more complex picture with a different balance between automation and human labour. Table 5 illustrates the outcome on capital and labour welfare of a fair ethical business development through I40 adoption.

Capital	Labour Welfare
Reduced lead time	Increased number of workers
Increased output quantity	Better work conditions for labour

Capital	Labour Welfare
Reduction of defect rates	Workers act as supervisor of I40 technologies
Reduction of energy usage	Workers with improved digital competencies
Better coordination of units	Reduction of routine activities
Reduction of the maintenance time on the line	Continuous improvement of worker competencies through tailor-made vocational training
Reduction of paper usage	Increased task autonomy for workers
	Proficient knowledge of production activities of workers
	Task enriched for workers
	Reduction of work incident
	More responsibility for workers
	Extra compensation for workers

Table 5 Outcome of a fair ethical business development in Industry 4.0 adoption

To reach a fair balance between capital and labour welfare benefits, the organisation exploits I40 technologies to automate repetitive and dangerous activities, where human errors are common and work accidents can happen. The resulting I40 assembly line is semi-automatic and disrupts one job position along the line and one job position of the logistics unit, where two workers conduct the pre-assembly operation and drive forklift, respectively. Nevertheless, the organisation avoids such workforce reduction along the line, increasing workforce duties. In our case, assembly line workers operate both as machine supervisors and quality controller of colleagues' operations. With a profound knowledge of the production process machinery, maintenance workers take on the role of technology developers to reduce simple maintenance activities, and logistics workers act as automated forklift supervisors. This workforce empowerment leverages job rotation, job enrichment, and vocational training that allows addressing operational knowledge reduction and developing a poly-specialistic worker.

Thus, the novel assembly line generates value through a strong interplay between technologies and workers. I40 technologies are deployed to conduct faster operations, and poly-specialistic workers are developed to conclude the assembly, supervise I40 technologies and continuously optimise the assembly line.

Moreover, I40 technologies embedded some feature for the competence growth of the workforce and performance at the same time. The measurement of time for each production phase and the mentoring and the training-on-the job ensure both managerial visibility on individual and overall performance and the continuous improvement of workers performance. The development of teams behaviour allows workers to help each other and learn from each other's experience.

Applied in this way, I40 technologies support labour welfare. The organisation maintains stable employment, and workers experience better work conditions and enriched duties. At the same time, the I40 adoption support business capital by improving production efficiency through a shorter lead-time, reduced costs for resources use and maintenance, higher quality product, and more fine-grained control over the assembly line. Such added value reflects a stronger market position of the organisation that can also continue to defend job positions and integrate new workers as soon as the increase in production requires new human resources. The organisation also shares their increasing profit with workers with extra compensation.

Therefore, answering our research question, the principal proposition resulting from our investigation reads as follows.

Principal Proposition. I40 technologies deployed with a worker-centric approach help organisation undertake a fair ethical business development and support a fair balance between capital and labour welfare benefits. I40 technologies automate repetitive and dangerous activities, and workers reduce routine work and enrich their duties taking on supervision activities on the assembly line. The production is more efficient,

and workers acquire competencies to work with I40 technologies and a higher level of knowledge of the production activities.

To deeper understand how an organisation employs I40 adoption to a fair ethical business development, we further analyse the main proposition.

The extant literature reports that I40 technologies automate production activities according to their functionalities, neglecting the workforce's role along the line with a resulting job disruption, particularly for low skilled workers (Frey & Osborne, 2017; Haleem & Javaid, 2019; Kang et al., 2016).

In our case, the organisation addresses such consequence by following a participative approach. Workers are involved during the I40 development. They provide advice on the I40 technologies to purchase and activities to automate according to their working needs. The organisation is receptive to such advice and tends to follow this recommendation by including different units, particularly the maintenance unit, that knows how the production line operates and can help implement and program these technologies. As a result, I40 adoption is used to automate only unhealthy and repetitive activities for workers, where mishaps are common.

Moreover, the management maintains stable employment by counterbalancing the loss of the workforce activities with novel duties that are more abundant in creativity and autonomy. The I40 workforce is enriched with supervision, maintenance, configuring, monitoring, and continuously improving the pieces of technology. Thus, the novel assembly line is semi-automatic and deliver value with a strong sociotechnical interplay between technologies and workers. The production is more efficient with less down-time, and the workforce experiences better workforce conditions and ergonomics and enriched tasks (Braccini & Margherita, 2019; Erol et al., 2016; C. K. M. Lee, Lv, Ng, Ho, & Choy, 2017; Shamim et al., 2016).

Therefore, we propose the following sub-proposition:

Sub-Proposition 1. The management follows a participative approach to select the I40 technologies to adopt and the activities to automate. I40 technologies automate only repetitive and unhealthy operational activities leaving room for enriched tasks for the workforce, which are the supervision and continuous improvement of I40 technologies. The resulting I40 assembly line is semi-automatic and operates with a strong sociotechnical interplay between workers and technologies.

The development of an I40 assembly line leveraging on this sociotechnical interplay is challenging for the management. Although the required I40 technologies can be purchased and programmed, these poly-specialist workers need to be developed and require a proper education according to the tailor-made activities they perform along the I40 assembly line. In our case, such poly-specialist workers supervise and address potential mechanical issues of I40 technologies and keep conducting most of the assembly activities. Such human activity configuration does the practice of replacing the traditional workforce with more IT-skilled workers detrimental for the organisation because it leads to a loss of know-how and expertise related that hampers all the peculiar manual activities for the completion and customisation of the production (Margherita & Braccini, 2020; Sony, 2020).

Au contraire, the management develops life-long training paths – vocational training, mentorship, and training on the job – to reskill traditional workers. Thus, workers can understand how the I40 technologies operate along the line and how they can manage it. Such courses do not prepare workers to merely start and stop the technologies in case of mechanical issues but to develop digital competencies that allow poly-specialist workers to use complex human-computer interface systems of I40 technologies and deal with mechanical issues. This is the case of AR application that supports step-by-step workers on maintenance activities on cobots and different machinery or tracking systems that allow workers to send I40 to send feedback to increase their safety and communicate with other workers.

Such training courses are not held only during the adoption process, but they are periodically given to workers to present the latest updates of the I40 technologies and their use.

Therefore, we propose the following sub-proposition:

Sub-Proposition 2. The management develops life-long training paths to build poly-specialistic workers with overlapping competencies related to advanced management of the I40 technologies and related to the assembly of products. Thus, I40 technologies promote a more efficient and automated production process to support the capital and growth of workforce digital competencies and enriched duties for labour welfare.

Finally, the interplay between I40 technologies and workers leverages poly-specialistic workers possessing a proficient knowledge of the entire production activities to operate in the I40 assembly line. They are in charge of conducting complex assembly activities and cobot's activities when it is offline. Although the management supports knowledge accumulation by reshaping the production process into several easy steps, including straightforward activities and automating repetitive activities. Workers experience a lack of knowledge to assemble the entire product, fix finished products and the phases performed by robots, and a hyper-specialisation for the activities in charge (Bednar & Welch, 2020; Mehri, 2006). In our case, the management addressed these issues adopting I40 technologies for knowledge sharing: AR application provides visual instructions to assemble the component and traceability system allows workers to communicate with colleagues. Then, the management assigns the workforce the task of managing cobots, taking their tasks when they are offline, and interchanging the workforce between the traditional and I40 assembly lines. Furthermore, the task easiness, peer supervision, and the rotation of workers across phases and lines stimulated the growth of group dynamics that support performance and knowledge sharing.

Therefore, we propose the following sub-proposition:

Sub-Proposition 3. I40 assembly line requires poly-specialist workers with a high level of knowledge of production activities to operate with I40 technologies. To this end, the workforce needs rotation, teamwork attitude, task easiness, peer supervision. I40 technologies accommodate knowledge sharing with a specific feature. Thus, I40 technologies increase organisational performance to support the capital and support knowledge development and better workforce conditions for labour welfare.

5.1 Implication for researchers

Our study proposes four theoretical propositions to explore how organisations undertake a fair ethical business development through I40 adoption to support a fair balance between capital and labour welfare benefits. We believe that these propositions can contribute to the genesis of a research agenda for future studies in the field. Therefore, we encouraged researchers to develop these propositions further by adopting a number of methodological angles, such as qualitative – especially action research and Fs/CQA analysis – and quantitative approaches.

We based the study on an Italian production branch of a large organisation producing electrical switches. Thus, we encourage researchers to replicate this study by selecting small-medium enterprises operating in different sectors and based in different countries from Italy because we expect that fair ethical business development of I40 adoption may vary in these cases (L. Li, 2018). Since the I40 adoption high cost (Sony & Naik, 2019), small-medium enterprises have less capital to invest in such a transition than a large organisation. A different production process may vary the I40 technologies to adopt and the tasks to automate with a result different balance between extensive automation and labour. Similarly, countries different from Italy can have different types of national funds (or any) to help the organisation adopt I40 technologies (Kang et al., 2016).

Our results show how the management enriches the duties of assembly line, maintenance and logistics workers to compensate for the reduction of routine activities due to I40 automation. Owing to the limited

body of knowledge regarding fair ethical business development of I40 adoption, we focused on operational workers because the current I40 technologies mainly impact their units. However, we noted that the tracking system and data analytics automatically produce reports and analysis previously compiled by middle managers. These technologies, combined with the advent of artificial intelligence, increase the automation of these activities and open a potential job disruption for middle management. Therefore, further studies should investigate a fair ethical business development of I40 adoption embracing the entire organisation and the middle management, developing a research proposal to advance the knowledge accumulation faster.

The results of our case analysis show the importance of competencies for the I40 workforce and how competencies are built up. Indeed, the study portrays that workforce needs distinctive digital competencies for the management of technologies to remain in the organisation that is built by a lifelong learning path. Further studies should investigate whether management develops a lifelong learning path and how management can measure competence growth. We also encourage researchers to explore a competence catalogue that can serve as a reference for practitioners to develop tailor-made courses for I40 competencies.

Finally, our work confirms that automation of production activities impedes workers from acquiring the proper knowledge to conduct effective operations along the line (Bednar & Welch, 2020; Burton-Jones, 2014). Although I40 adoption promotes knowledge sharing by the features of AR application and the traceability systems (D. Li et al., 2019), these features are not sufficient to stem the decreasing expertise and know-how of the organisation. In our study, the management couples this I40 feature with teamwork and job rotation to address this issue. Further study should focus on the development of tailor-made knowledge management for I40 capable of knowledge acquisition, documentation, transfer, creation, and application. On which the organisation can base its competitive advantage.

5.2 Implication for practitioners

Practitioners can use the study as guidelines to achieve a fair balance between capital and labour welfare benefits through I40 adoption. The transition to the I40 production process does not automatically imply the reduction of employment level. Practitioners should employ I40 technologies to automate repetitive tasks and prepare the workforce to conduct novel knowledge-intensive activities, including technology supervision with a higher degree of autonomy. In this period of recession due to the COVID-19, the deployment of I40 technologies with a worker-centric approach is a valid strategy for fighting the economic crisis allowing to increase production output and defending job positions for the community.

To exploit the full potential of I40 adoption, the pieces of evidence of our case mandate organisations to develop a lifelong learning path to enrich workforce competencies on I40 technologies. Vocational training plays a crucial role in I40 adoption and shall be tailor-made to each worker employed in the assembly line. Training-on-the-job and mentorship conclude the workforce training straightening knowledge of production activities. Still, the study illustrates the importance of teamwork attitude, job rotations to maintain a high level of knowledge of the production process for the workforce.

Moreover, our study shows that including the workforce during the I40 innovation project reduces the resistance to changes. We also show that maintenance workers can help the cobot adoption and programme customised cobot movements according to the assembly thanks to their knowledge of the production process.

6 Conclusion

Our study is motivated by the lack of studies that explores how I40 adoption help manufacturing organisations undertake a fair ethical business development in order to support a fair balance between the benefits of capital and labour welfare. We addressed this gap by conducting a single case study analysis of the production unit of the Italian branch of an International electrotechnical organisation. The results show

that I40 technologies deployed with a worker-centric approach help organisations find a fair balance between capital and labour welfare benefits. I40 technologies improve the production process by automating repetitive and dangerous activities to support the capital. At the same time, I40 technologies support labour welfare because they are deployed to improve workforce conditions and support workforce empowerment through reduced routine work and enriched duties. The resulted production line is semi-automatic, and the level of employment remains stable along the line. Workers need lifelong paths to acquire proper competencies to deal with I40 technologies. The automation simplifies the tasks assigned to workers with a potential downside in terms of knowledge fragmentation. The workforce is frequently rotated and assigned to interchangeable tasks having poly-functional and overlapping expertise to address this downside. Working in this way, the workforce developed a teamwork attitude and can see their roles enriched by taking on technology managerial tasks. We further propose four theoretical propositions to advance our study.

We acknowledged that our study has limitations. The generalizability of the findings may be limited due to the selection of a single case organisation. Although we acknowledge this methodology accounts only for inductive generalisability, we believe our results to be significant in terms of external validity for two reasons. Firstly, we chose an organisation leader of the sector operating in the Italian context that is the second-largest manufacturer in Europe (Margherita & Braccini, 2020). Such context is similar to other European, American and Asian countries, where the government provides national funds to purchase I40 technologies without considering the societal effects of these technologies (Kang et al., 2016; L. Li, 2018). Secondly, the organisation is a leader of a large cluster of large and small-medium organisations, for which it will guide the I40 transition in an ethical manner. Therefore, the solutions deployed by ELECTRIC will be reproduced in the other companies of the cluster. Therefore, we retain the study generalisation is reinforced because our findings are not just idiosyncratic to a single case but will be replicated in several organisations of this I40 cluster.

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Appendix

In this section, we present the data structure and the interview excerpts of our studies.

2 nd level Coding	1 st Level Coding	Interview Excerpts
A More Efficient production process	Increased output quantity	"The gain of I40 line was a constant production, and we reach 800 pieces per day while before we only produced 400 pieces" (CPO). "We increased the productivity of the line with the cobots which assemble a part of the switch components faster than workers" (COO). "Thanks to I40 adoption, the organisation increased output quantity by 20%, shifting the production from 2,5 million to 3 million electrical switches and reaching a turnover of 550€ million" (distinguished national newspapers article).
	Reduction of defect rate	"We set challenging quality goals related to faulty products since the production drastically reduced defects rate" (Quality Manager).
	Reduced energy cost	"With the smart sensors, we can prevent the break of cylinders. We esteem that a damaged cylinder cost us 1500€ in electricity" (Mechanical Maintenance B). "With smart sensors, we can check if the maintenance of cylinders was good comparing the data before and after, thus we reduced energy waste" (Mechanical Maintenance B). "The organisation reduced the energy consumption by 30% thanks to I40 technologies and an electrical distribution control system" (Official balance sustainability statement).
	Reduced usage of paper	"With the AR application, workers do not bring all the manuals of the machinery to do maintenance, and they have a digital copy in the application" (Industrial Engineer 2). "We digitalized all the documents, the schedule of the orders by the MES thus we have reduced the papers" (Informatics Engineers A).
	Better coordination among units	"All the units are integrated with the MES and the management has current data of the production" (Informatics Engineers C)." "We reduce the intervention time from 9 to 20 minutes thanks to the systems (Informatics Engineer B)". "When we use the paper-based system, we have coordination issue while with the MES we integrate all the units. Now we work to integrate our partner of the supply chain" (COO).
Simpler activities for workers	AR facilitates maintenances activities Simpler assembly activities	"The AR application guides workers during the maintenance activities providing visual aid and digital instructions" (Industrial Engineer B).
	Simpler assembly activities	"Now workers only perform a phase of very easy assembly activities, before the production was more difficult because they assembled the entire product" (CPO).

2 nd level Coding	1 st Level Coding	Interview Excerpts
		“The MES automatically download the orders from the corporate SAP and manage orders to reduce the repetition of activities for the charging of components” (Informatics Engineer A).
Sustaining Knowledge of production process	Quick Job Rotation	“We have a very quick job rotation. workers change the activities every day since they change the workstation of the line” (CPO). “To make the work less repetitive, we have a very large job rotation” (Industrial Engineer A).
	Employing workers for cobots activities	“Now a worker is helping us to maintain the line constantly and does the same assembly of the cobots” (Supervisor Worker A). “When the components change in weight and shape, cobots often have problems assembling them. So, we help the line using a worker for cobots activities” (CPO).
	Altering workers between I40 and manual assembly line	“I work in both line the I40 line and the manual altering with the other workers thus I can assemble the entire products” (Worker A).
	Tailor-made course for workers thanks to technologies	“The tracking system allows finding in which assembly phase workers perform below standard thus we propose courses to increase skill and knowledge for those phases” (Quality manager).
	Knowledge of the process increased by teamwork	“We create quality gate along the line, and the worker checks the assembly of the previous worker addressing potentially assembly problems. Thus, workers can help the team to improve their production skill” (Quality Manager).
Workforce with more competences	Competences increased by vocational courses	“The organisation provides several vocational courses both for using cobots but also to work in the new assembly line. We provide them to apprentices and for experience workers periodically” (Public Relation Officer). “We received courses to manage the cobots. We learnt how to block the robots and how to restart it” (Supervisor Worker B). “For maintenance unit was a challenge to program the cobots, we followed a course for coding. This coding skills and our knowledge of machine anomalies really helps us to set up the cobots” (Mechanical Maintenance 1). “During the I40 adoption, training per years of the workforce passed from 12 hours to 16 hours on average” (Official balance sustainability statement).
	Knowledge of technologies increased by training-on-the-job	“We received training on the job to use the cobots and address their issues” (Worker 1). “Now workers of the assembly line know better all the activity phases and how to manage cobots thanks to training on the job” (CPO).
	Knowledge of technologies increased by mentorship	Three supervisor workers provided mentorship to us to improve our competencies in the use of the cobots.” (Worker A).

2 nd level Coding	1 st Level Coding	Interview Excerpts
More duties for workers	Increased Task Autonomy	"Now worker can directly order the broken piece through the AR app to conclude the maintenance. Before, workers had to call the maintenance unit" (Informatics Engineer B). "In the new assembly line, we workers download the order from the MES, we change components on the line, we help each other to maintain constant the production." (Supervisor Worker B)
	Assembly line workers as a technology supervisor Logistic workers manage automated forklift trips	"Now the workers that operate with cobots, supervises these robots using a computer. They can block them or restart them. While logistics workers now manage the forklifts" (COO).
	Assembly line workers as a technology supervisor	"Now workers supervise the cobot. Before they only perform manual operations and now, they are a sort of technician. It is a great improvement for them" (CPO). "Now workers have to supervise the cobot which has micro collisions, and their work is very important. Sometimes cobots break the piece of the vision system has problems, and they afford to restart or block the system. They help each other and charge components on the line" (Mechanical Maintenance A). "Now workers have to supervise the cobot which has micro collisions and their work is very important. Sometimes cobots break the piece of the vision system has problems, they afford to restart or block the system. They help each other and charge components on the line" (Mechanical Maintenance A).
	Assembly line workers with maintenance duties	"With AR application, workers do simple maintenance activities because the AR application does visual instructions" (Industrial Engineer B).
	Assembly line Workers as quality assurance	"Along the line, the worker performs quality control of the assembly of the previous worker" (CPO).
	Maintenance workers as a technology developer	"My unit, the maintenance, did scouting of these technologies and then we programmed the cobots and vision system. Before we only fix machines" (Mechanical Maintenance A). "We used workers with knowledge on I40 technologies to study and develop the application of these technologies, and they also did a sort of scouting. They also do focus groups with universities and start-up" (COO).
Reduction of repetitive activities	Reduction of repetitive activities for assembly line workers	"I40 for us is a way to improve efficiency and to stimulate workers. We automated repetitive assembly activities with cobots. They assemble three small parts. Workers can do more complex activities" (COO). "We automated with cobots only activities with low value-added where errors often occurred. Workers were excited about this" (CPO). "We automated repetitive activities through cobots where mistakes often occurred" (Products engineer).

2 nd level Coding	1 st Level Coding	Interview Excerpts
		"Along the line, we automated by cobots assembly phases repetitive and unhealthy for workers" (Mechanical Maintenance A). "Workers now see automated repetitive activities along the line, and at the same time, the organisations will increase employee number by 122 units" (Distinguished national newspapers article).
	Reduction of repetitive activities for maintenance workers	"Maintenance unit reduced their routine activities, assembly line workers with AR do these simple activities" (Mechanical Maintenance A).
	Reduction of repetitive activities for logistics workers	"Now the logistics reduce the time spent for the trips in the plant since the forklift is programmed to do so" (Supply Chain/ Operation Engineer).
Safer Workplace	More ergonomics workstation	"The redesign of the line thanks to I40 makes the workstation more organised and ergonomics" (Supply Chain/Operation Engineer). "We reach the golden zone for the picking. We adopted shelving units along with the I40 assembly which assures safe handling between 50-120 cm" (Supply Chain/Operation Engineer).
	Fewer microplastics in the production process	"Along the line, we automated by cobots a pre-assembly phase which released microplastic. Now the line is safer because these microplastics remain in the cobots area, and worker do not inhale them. We pointed out this problem during the adoption process in focus group." (Mechanical Maintenance A).
	More organised workplace	"The workplace is more organised than before thanks to the lean, but also thanks to workers that are encouraged to take care the workplace organised because we give extra money. We experienced less injuries." (Products engineer)
	Zero work-related fatalities	"There are no employee work-related fatalities in the organisation" (official balance sustainability statement).
Knowledge reduction of the production process	Difficulties for workers to repair finished products	"Workers do not know well the production process especially activities to repair the products." (CPO).
	Limited knowledge for assembling an entire product	"The traditional production process pushes workers to know all the activities of the entire production process while with this new line workers know only a small part of the production process" (CPO). "In the traditional line, we knew which product we assembled, I made it and I know how I assembled it. If there are some problems and the customer sends it back, I can understand my errors and improve my way of assembling. Now, it is possible because I only put some parts of the switch and in case of errors, we don't know who made the errors. We only do movements not assembling" (Workers Supervisor A). "At the end this way of producing consists of only repetitive activities and not a production like in the traditional method" (Worker B).

2 nd level Coding	1 st Level Coding	Interview Excerpts
	Lack of knowledge of cobots assembly activities	"Since cobots assemble product constantly, we firstly teach how to assemble manual phases, after we teach the cobot phases in case of cobots problem. (CPO)"
Reduction of human activities	Reduction of production activities for workers	"Now our line has cobots. Cobot does the work of one or two people" (Worker Supervisor B).
	Cobots substitute one human workstation Reduction of production activities for workers	"We changed a manual workstation with a cobot that performs repetitive tasks" (CPO). "We design the new assembly line without a human workstation which we substituted with a cobot that performs faster" (Mechanical Maintenance A).
	Logistic workers no longer drive forklifts	"Now logistics don't drive the forklifts which are moving in autonomy" (Products Engineer).
	Reduction of routine maintenance activities for the maintenance unit	"Now we are focused on programming cobots rather than does routine maintenance on the line" (Mechanical Maintenance A). "Workers of the assembly line performs simple maintenance activities on the line which were previously performed by the maintenance unit" (Informatics Engineer C).
Lack of digital competencies to handle I40 technologies	Low knowledge of technology feature	"We teach workers since they are not familiar with the feature of these technologies" (Mechanical maintenance A).
	Lack of informatics competencies for the workforce	"Workers need to have competencies for working with these technologies beyond the operative skills. But it is difficult to acquire them" (Worker B). "We need workers also for the assembly line with informatics competencies. Now it is a prerogative to be hired" (COO).

Appendix 1 Data structure and empirical findings

Emanuele Gabriel Margherita is a Postdoctoral researcher at the Department of Economics Engineering Society and Business (Dipartimento di Economia Ingegneria Società e Impresa - DEIm), University of Tuscia, Viterbo (Italy). He holds a PhD in Economics, Management and quantitative methods from University of Tuscia, Viterbo (Italy). He was a visiting student at Information Systems Department of Agder University (Norway) and the LENTIC research centre at Liege University (Belgium). His research focuses on how Industry 4.0 technologies create sustainable value for organizations and society. His work has appeared in journals such as *Information Systems Frontiers* and *Sustainability*. His research has been presented at STPIS, WOA and ItAIS conferences.

Alessio Maria Braccini is a Full Professor of Business Organization and Information Systems at the Department of Economics Engineering Society and Business (Dipartimento di Economia Ingegneria Società e Impresa - DEIm), University of Tuscia, Viterbo (Italy). He holds a PhD in Management of Information Systems from the LUISS Guido Carli University, Rome (Italy). His research interests concern the study of the impact of ICT at the individual, team, and organizational levels. His research has appeared in journals such as the *Information Systems Journal (ISJ)*, *Information & Organization (I&O)*, *International Journal of Accounting Information Systems (IJ AIS)*, the *Government Information Quarterly (GIQ)* and the *Communications of AIS (CAIS)*. His work has also been presented at ICIS, ECIS, BIS, MCIS, ItAIS, and WOA conferences.

Author Contributions: The authors have contributed equally to the paper. All authors have read and agreed to the published version of the manuscript.