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Digitalized Drones in the Steel Industry: The Social Shaping of Technology
Les drones dans l’industrie sidérurgique: contours sociaux de l’avènement de cette technologie

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Résumé de l'article

Les nouvelles technologies numériques sont souvent présentées comme une force inévitable et déterminante qui engendre un risque de chômage technologique et de fin de travail (Lloyd et Payne, 2019). Dans le secteur manufacturier en particulier, l’avènement du numérique (*digitilization* en anglais) est appelée « Industrie 4.0 », un terme qui a, d’abord, émergé en Allemagne en tant que politique économique et industrielle centrale et qui a, ensuite, pris une résonance plus large à travers l’Europe (Pfeiffer, 2017). Dans cet article, nous explorons les implications sur le lieu de travail d’une innovation spécifique de l’Industrie 4.0. Nous examinons l’insertion de la technologie des drones — en tant qu’exemple actuel de l’innovation technologique numérique industrielle — dans l’industrie sidérurgique.

Se situant dans le cadre des débats sur le lieu de travail numérique, l’article introduit une discussion sur la relation entre les forces matérielles de production et les relations sociales dans lesquelles elles sont intégrées (Edwards et Ramirez, 2016). En nous appuyant sur les données d’entretiens de deux sites industriels européens, nous suggérons que l’utilisation croissante des drones sera probablement entravée par un certain nombre de facteurs sociaux, économiques et juridiques, dont les effets sont, au mieux, extrêmement difficiles à prévoir. Introduits pour leur potentiel en tant que dispositifs permettant d’économiser du travail, les drones offrent apparemment un moyen plus sûr et plus efficace de vérifier les défauts dans les zones éloignées ou inaccessibles.

Cependant, alors que les employeurs peuvent imaginer que les technologies numériques, comme les drones, sont à même de remplacer, d’éliminer ou intensifier le travail, les réalités des lieux de travail décrits par nos interviewés révèlent une insertion très contingente. Nous mettons en évidence plusieurs de ces éventualités, avec des exemples de différences entre les intérêts des métallurgistes et ceux de leurs employeurs, dans le but de discuter de la manière dont l’insertion des technologies numériques sera finalement façonnée par le pouvoir, les intérêts, les valeurs et les visions qui prévalent sur les lieux de travail, ainsi que dans le système politique et la culture publique au sens large.

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Digitalized Drones in the Steel Industry: The Social Shaping of Technology

Dean Stroud, Victoria Timperley and Martin Weinel

In this paper, we draw on interview data from a project that explores the insertion of digital technology into a manufacturing context, i.e., drones in the steel industry. The paper identifies the potential for digital technologies to be disruptive, but draws attention to the social shaping of perspectives on technology and, thus, challenges overly deterministic narratives. We discuss how the insertion of digital technologies will ultimately be shaped by the power, interests, values and visions prevailing in the workplace, as well as in the wider polity and public culture. In this way, we bring to debates on the digital workplace a discussion of the relationship between the material forces of production and the social relations in which they are embedded.

KEYWORDS: digitalization, industry 4.0, technological innovation, drones, industrial relations.

Introduction

Currently, there is much debate about the emergence of the digital workplace and the implications for work and employment of new robotic and artificial intelligence (AI) technologies (Briken *et al.*, 2017). The so-called 'Second Machine Age' or 'Fourth Industrial Revolution,' with self-driving cars, 3D printing, and big data, promises new threats (jobless futures, heightened surveillance) and opportunities (more highly skilled and creative jobs) when it comes to the distribution of work and the quality of jobs (Brynjolfsson and McAfee, 2014; Schwab, 2016). And yet, as Lloyd and Payne (2019) suggest, many accounts of new technologies are speculative and heavy on anecdote, while lacking a fuller understanding of what their insertion into the workplace will mean for work, workers, and society in general (see Spencer, 2018).

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Digitalization in manufacturing is often referred to as 'Industry 4.0', a term that emerged in Germany as a central economic and industrial policy and has taken on a wider resonance across Europe (Pfeiffer, 2017). The process of digitalization in manufacturing is a step forward from the ages of steam, electrification, computers, and automation to 'cyber-physical systems' of production on digital networking systems and to the centrality of 'big data' for 'smart factories' (Briken *et al.*, 2017). Specific digital innovations with potential for use in manufacturing include data analysis for predictive price and quantity forecasting, 3D printing for spare parts, digitally enhanced tracking and operational systems for improved maintenance functions, and use of drone technologies for gathering data on maintenance and production (Naujok and Stamm, 2017). For the steel industry, the focus of this paper, digitalization is the most recent feature of innovation aimed at achieving a 'business model transformation' for greater efficiencies and global competitiveness (Naujok and Stamm, 2017; Neef *et al.*, 2018).

With such developments in mind, we will explore the potential impact of inserting a specific piece of digitalized technology into the steel industry: unmanned aerial vehicles (UAVs), more commonly known as drones. As a topical and timely example of digitalized industrial robotization, the use of drones in the steel industry has the potential to improve efficiency and the safety of work. At the same time, whilst a relatively minor technological innovation in the context of the steel industry environment, they might also arouse some concerns about such matters as technologically induced unemployment and workplace surveillance.

The progress of technological innovations, like drones, and their insertion into the workplace are often viewed as inevitable, and such technologies are treated as a determining force that society can respond to only by mitigating the effects (see, *inter alia*, Lloyd and Payne, 2019 for a critical account). In this paper, we question the extent to which the social and economic impact of such technologies in industry can be determined in advance, and argue that their use will, ultimately, be shaped by the interests, values, and visions prevailing in the workplace and in the wider polity and public culture. In this way, we bring to debates on the digital workplace a discussion of the relationship between the material forces of production and the social relations in which they are embedded (see Edwards and Ramirez, 2016: 101).

To inform our discussion we draw on interview data from a European Commission-funded Research Fund for Coal and Steel (RFCS) project. It involves two steel plants based in Germany and Italy and has the aim of "substitut(ing) men [sic] in complex and expensive operations… [with drones]… related to the monitoring, maintenance and safety of steel plant infrastructures." These functions will be performed by drones in the near future, and our data suggest that such use is likely to be influenced by broader regulatory contexts (e.g., European legislation, health and safety regulations, data protection) and the specific characteristics of work, employment, and worker representation in the sector. Our analysis paints a picture that acknowledges the potential for workplace (and societal) disruption caused by digital technologies, but also draws attention to social shaping of perspectives on technology and thus challenges overly deterministic narratives (Wacjman, 2018).

In what follows, we provide a brief examination of the extant literature on the relationship between technology, work, and society in general, and on digital technologies in particular. We then detail the data gathering process and industry context before drawing on the interview data to provide an account of the issues outlined above. Finally, we offer a discussion and conclusions.

Technology, Work, and Society

In debates about the impact of technology on society, two opposing perspectives are commonly delineated. The first one emphasizes the inherently transformative consequences of technology. In mainstream, scientific, and commercial discourse, this is often an unambiguously positive story: technology is a rational solution to a technical problem, the 'technological fix' for productive inefficiency, food scarcity, infectious disease, infertility, global warming, and so on. In critical philosophy, political commentary and social science, on the other hand, the narrative of this perspective is more likely to be negative: technology, and the instrumental rationality it embodies, destroys jobs (Brynjolfsson and McAfee, 2011; Ford, 2015; Frey and Osborne, 2017; Spencer, 2018), ravages the natural environment and those who are most connected to it (Mies and Shiva, 1993), alienates people from each other (Marcuse, 1964; Turkle, 2011) and denatures our bodily relationship to the world (Gorz, 1989; Postman, 1993; Bowring, 2003).

Related discussions of technological determinism are focused specifically on the insertion of technologies into the workplace. Technology is viewed accordingly as hardware—equipment, instrument, or machine—and understood as an objective and external force that directly affects the organizational aspects of work. Such discussions in the literature position technology and its immanent characteristics as an independent factor, which wholly influences human interaction in the workplace, and determines the organizational dimensions of 'structure, size, performance, and centralisation and decentralisation,' as well as the individual dimensions of 'job satisfaction, task complexity, skill levels, communication effectiveness and productivity' (see Orlikowski, 1992: 400 for a critical account). Sabel and Zeitlin (1985) trace such conventional and narrow perspectives to Karl Marx and Adam Smith, and the view that technical progress follows development along the single path of efficiency (see Edwards and Ramirez, 2016).

The 'social shaping of technology' (MacKenzie and Wajcman, 1985) is a second perspective that grew out of sociological efforts to counter the perceived reductiveness of the arguments outlined above, and to bring *society* back into dialogue with technology in order to expose the limitations of 'technological determinism.' This perspective is, however, a broad church, and may embrace critical arguments, such as those of Langdon Winner (1980), who acknowledges that some technological artefacts may be inherently 'political', and more 'social constructivist' perspectives focused on the 'interpretative flexibility' of technology (see Elam, 1994). The line of argument we follow in this paper is that we cannot predict or understand the effects of technology without examining the social relations in which technology is or will be embedded, i.e., as understood in the capitalist relations of production more broadly and, more specifically, in the social (employment relationship) and material realities of workplace contexts. For example, studies informed by labour process theory have shown how, in commerce and industry, the reproduction of relations of power and control has been as critical to the development, selection, and deployment of workplace technology as the seemingly irresistible logic of efficiency and productivity (Braverman, 1974; Noble, 1984; Brown *et al.*, 2011).

MacKenzie *et al.* (2017) note that such labour process contributions have been caricatured by social constructivists as technologically deterministic. Indeed, new digital technologies are often framed as an inevitable and determining force that presents the risk of technological unemployment and the end of work (Spencer, 2018), particularly for people assigned to routine manual and cognitive tasks (Frey and Osbourne, 2013). Society responds to the job threats posed by these nascent technologies with such ideas as taxing robots and introducing a universal basic income, but typically, the focus is on education, reskilling and lifelong learning to relocate workers elsewhere (Lloyd and Payne, 2019). However, Wacjman (2018: 168) questions this "inevitability" and "the widespread assumption that digital technologies… [are making us]… mere hostages to the accelerating drive of machines."

Of course, it might be noted that the aim of the RFCS project is to employ digitalized 'machines' to accelerate maintenance functions, but there is no temporal logic *inherent* in digital technologies. The broader argument is that digital "technologies are not neutral, value-free tools that simply drive changes in society… but inherently social… crystallisations of society' that transform 'how we work, live and communicate" (Wacjman, 2018: 169-171). Indeed, we are mindful of technologically deterministic predictions, and that any analysis of "the future role of the digital in capitalism [must] embrace an understanding of varied contexts, power relations, choices and decision structures and the capacity for resistance" (Thompson and Briken, 2017: 258). Thus, we might take our lead from Wacjman and others to steer away from the technological determinism of digitalization to take the 'dominant view' of technologies as socially shaped.

At the same time, it is worth noting literatures that offer an account closer to 'soft-determinism' and raise questions about the 'effects' of 'Industry 4.0' and digital technologies—technology about which we can only speculate, not least because it is at an incipient stage and, in the workplace, represents a high level of discontinuity. The point here is that analysis of the 'effects' of 'new, new technologies' and the specific properties of, for example, drones will help inform collective decisions to embrace or resist the technology (Edwards and Ramirez, 2016: 99). This approach will open up room for debate over regulation of capitalist social relations and workers' capacity (where it exists) to exercise collective power in the workplace and thus shape technology's impacts on the material realities of their work and employment.

This is an important dimension of analysis, which begins to highlight the role of 'powers' and 'interests' in shaping whether and how 'Industry 4.0' technologies are inserted into the workplace and the socio-political choices affecting the level and distribution of work and the quality of jobs created or redesigned around them (Lloyd and Payne, 2019). The tension exposed here is between the "role of technology" as "digitalised artefacts of advancement" (i.e., presenting new opportunities for growth and decent work and possessing "potential [as] instruments of collective solidarity") on the one hand and the potential for their use as "instruments of atomisation and control" on the other (Pfeiffer, 2017: 35-36).

Such accounts only begin to touch on the long history of debate over the relationship between technology, society, and work. Nonetheless, we are laying the foundations for discussion of our interview data and emergent questions on the 'inevitability' of digital technologies for work, employment, and society.

Methods

Funded by the RFCS, the project informing this paper explores the potential applications of drones in the steel industry. Project partners included the authors of the paper, the two steel plants that provided the case-study sites (one in Germany; the other in Italy), a German drone manufacturer and an Italian one and the managing partner—an Italian engineering consultancy. Our project role was to investigate the 'human factors' in the possible use of drones in steelworks, with a focus on roof and chimney inspection and monitoring in the Italian case-study plant (SteelCo.IT) and on gas pipe inspection and monitoring in the German one (SteelCo.DE). We were tasked with exploring the impact of drone use on workers in two ways:

- *Social requirements* e.g., safety- and surveillance-related risk and harm arising from drone activity, including the regulatory and ethical implications of being observed at work and the risk arising from new technologies (e.g., job losses, occupational safety, etc.).
- *Impact on work activities* e.g., what changes to steelworkers' work might arise from introducing drones, such as for new means of roof inspection and new forms of data.

We conducted case studies of the two steel plants, interviewing various personnel at each site (see Table 1). The research was employee-centred, the aim being to explore the potential benefits and risks of drone technology as it might be utilized in the industry, and as viewed and understood by the steelworkers.

TABLE 1
List of Interviews

Case Site	Area of Drone Inspection	Interviews	Section Covered	Professions Covered	Position Covered
SteelCo.IT	Roof Chimney	4 groups 12 workers	• Galvanizing • Cold rolling • Steel shop • Roof inspection	• Roofers • Systems engineers • Maintenance engineers	• Section leaders • Team leaders • Operators
SteelCo.DE	Gas pipe	5 groups 13 workers	• Works Council • Human Resources • Occupational Health • Service Division • Operators	• Maintenance engineers • Operators • Human Resources	• Team leaders • Section leaders • Operators • HR Management

Four group interviews were conducted with 12 workers at the Italian plant over two days in March 2017. The participants included section leaders, team leaders, and operators, and their technical roles ranged from roofers to system engineers and maintenance engineers. The interviews were conducted with the aid of a translator supplied by the company, and this research work was supplemented by a tour of the plant. At the German plant, five group interviews with 13 workers were conducted over three days in February 2018 (plus one follow-up interview in 2019). Nine of the participants worked in the Technology, Service and Energy (TSE) division of the plant, one was from Human Resources, and two worked in another nearby plant owned by the same company. The interviews were conducted in German by a bilingual research team member and were with team leaders, section leaders, and operators, and their technical roles ranged from maintenance engineer to central administrator. The researchers were again given a tour of the plant, including sites where a drone had been tested and deployed as part of the project.

The European Steel Industry

Our discussion of digitalized drone technologies concerns specifically the European steel industry, which has experienced significant privatization, rationalization, and restructuring over recent decades. All of these processes have considerable implications for the workforce. Whilst the industry has high levels of worker representation (Beguin, 2015), it has proven difficult for worker representatives to defend the workforce against substantial downsizing. The industry workforce was reduced from 800,000 (EU15) in 1980 to 320,000 (EU28) in 2018, and a further loss of 30% is anticipated by 2025 (Eurofer, 2018). The reduced workforce of today is differently recruited and organized (e.g., high-performance work systems [HPWS] are now widely utilized) and more highly skilled and qualified (e.g., Bacon and Blyton, 2000; Stroud, 2012). This detail is important because it provides the context in which the steel industry workforce experiences processes of innovation.

The focus is constantly on innovation across European industry as it struggles to remain competitive. Not all innovation is technological, e.g., the introduction of teamwork to industry during the 1980s and 1990s signalled innovative efforts to improve productivity and performance at an organizational level (Bacon and Blyton, 2000). Today, however, the principal focus of innovation is the technological transformation of industry through digitalization. Digitalization is not simply the transfer from analogue to digital format for data and documents; it is the networking of business processes through efficient interfaces and integrated data exchange and management (Bogner *et al.*, 2016). In the steel industry specifically, an intelligent combination of process automation, information technology, and connectivity has enabled the digitalization of steel production to go far beyond conventional automation of industrial production (Murri *et al.*, 2019). The drone technology we discuss represents one such example of innovation in this direction.

Inserting Drone Technology into the Steel Industry

In what follows, we will explore worker perspectives on the scope of drone insertion into the steel workplace, focusing on our two case-study plants. We will begin with Italy and then provide an account of the plant in Germany.

SteelCo.IT

The Italian steel plant is one of the largest steelworks in Europe, with a capacity of 10 million metric tons and an on-site workforce of around 20,000 (twelve thousand directly employed). It has been mired in some controversy in recent decades (mainly related to pollution) and since our visit has been acquired by a large multinational competitor. During our negotiations for access to the plant it became clear that relations between management and the trade unions were strained, an apparent reflection of the more general state of industrial relations in Italy (e.g., Hyman, 2001; Culpepper and Regan, 2014). Despite such difficulties, the interviewees noted that on-site trade unions were always consulted on the introduction of new technologies, including drones. Yet, at the time of the interviews, it became clear that the aims and objectives of the RFCS-funded project had not been made widely known to workers at the site.

Roof inspections, primarily to prevent, identify, or repair leaks, are costly and time-consuming and provide one focus for the RFCS project in Italy. They normally require mobile lifters and/or externally subcontracted scaffolding and walkways, and at some locations production must be stopped to ensure the inspection or repair is conducted safely. As the foreman of the roof repair team remarked, "It may take just ten minutes to repair, but two days to get to where the work needs to be done."

A cold rolling mill technician expressed confidence that drones could be used to identify roof damage before it became significant enough to cause a leak. Where water was already leaking on the inside but the external point of entry was not yet known, drones with thermal cameras could be used to track the hidden flow of the water and generate a visual map of the distribution of humidity in the roof structure.

None of the roof inspection team members had thought much about the use of drones for roof monitoring before the interview, but all of them appeared to view their use favourably. The plant has several hundred buildings, many of which date back to the original construction of the plant in 1965. The interviewees reported that lack of money and personnel meant that roof maintenance was primarily reactive, with little time available for routine, preventative inspections. The danger of working at heights was also mentioned as something that drones could reduce. Chimney repairs—though done by certified external contractors, as per regulations—could also be accelerated if each section's civil works specialist used drones for pre-repair inspection.

When asked about the potential drawbacks of using UAVs, some of the roof inspection team members noted how important touch, sound, body weight, and pressure are to establishing the physical integrity of roofing materials and structures, saying that purely visual monitoring of roofs might still be an inadequate replacement for an engineer's physical presence. This caveat aside, there was a surprising absence of concern about the potential job-destroying impact of drones amongst the Italian plant participants, and no one raised the issue of surveillance, data protection, or privacy—but when the interviewers mentioned that issue, the interviewees cited data protection and workplace regulations (as applied to fixed cameras, which are used on the site). On job losses, as explained further below, because the roofing team was already struggling to keep up with the number of necessary repairs, and since drones yet cannot perform repairs by themselves, the lack of concern was perhaps understandable.

From the roofing team's perspective, whether the team—currently numbering 26 personnel for the whole plant—expands or contracts appears to be, ultimately, dictated by the importance of roof maintenance to management, and not by the impact of technology. The regular use of supplementary external contractors (for scaffolding work) also suggests that cheaper labour may be a greater threat to the roofing team's jobs than new technologies—although out-sourced scaffolders were thought to be the ones most at risk from drones of job loss. One might argue that the roofing team had a tacit sociological understanding of the 'effect' of technology at work, and possessed sufficient experience with the capital-labour relationship to read future technological developments through the prism of the social relations of production (see Edwards and Ramirez, 2016).

Interviewees also suggested that drones could be used for a wider range of other inspection uses, e.g., leaks in boilers, and gas-pipe leaks. For example, whilst these workers acknowledged the challenges of flying drones in restricted spaces, the use of a drone to conduct boiler inspection would be quicker, cheaper and, important from a worker perspective, safer. Improved safety—drones being able to fly over dangerously high structures, at relatively high temperatures, in toxic air, and in darkness—was for most of the workers interviewed the biggest attraction of using UAVs:

> If it's dangerous and uncomfortable work, then a person is happier about being replaced by a machine. On the roof in winter it's cold, in the summer it's hot. It's also very high up. (Galvanizing, Maintenance Engineer, Section Leader, SteelCo.IT)

But, better safety was not believed by the workers to be a priority of the plant managers. Instead, management was said to have a highly productivist ethos and to be slow and cautious on innovation, with investment decisions driven by the proven promise of quick gains in output, and the recently created Innovation and Research Department relying exclusively on European funding for its budget:

> Every project we have or would like to start, the first question is always cost-benefit analysis; how much will it save? The priority is production. We have to run the plant

> first of all, then the innovation projects… We always need proof-of-concept, we have to prove definitively that use of a drone will save two weeks of inspection. (Steel Shop, Maintenance Engineer, Team Leader, SteelCo.IT)

The workers' conviction that drones would not endanger their jobs was perhaps another reason they believed managers would not see the benefits of this technology. It was also noted that some technical staff disliked changes because 'innovation brings risk':

> In the maintenance team, there are some people…technicians and engineers … innovation means risk… and also fault… not everybody accepts to leave what he knows very well, even if it's obsolete. (Steel Shop, Maintenance Engineer, Team Leader, SteelCo.IT)

On the issue of surveillance specifically, as an area of risk, the safety coordinator for the galvanizing line area pointed out that cameras were already widely used in the area—though for legal reasons (i.e., data protection), the cameras were trained on the equipment and not on the people, perhaps this explains why plant workers did not associate the use of drones with unwelcome or invasive surveillance. Further, union density is high at the plant, and all interviewees spoke of the need to consult with the trade unions and seek agreement on the introduction of new technology.

Data analysis and interpretation are also highly skilled and time-intensive activities that require incorporating further labour power and skills investment, from the interviewees' perspective, into existing teamwork structures:

> We are automation people so we know machines replace people, but more maintenance people are needed after implementation, with higher training… The use of very modern machines requires from our maintenance point of view … better training, because there are some things you can learn from experience, but these are more dedicated things so you need better [specialized] training … (Cold Rolling Mill, Maintenance Engineer, Section Leader, SteelCo.IT)

Perhaps surprisingly—given some recent redundancies—the widespread agreement that the plant was struggling with a labour shortage also led many of the workers to believe that any savings in labour time made possible by drones would simply allow them to be redeployed to, or reskilled for, other urgent jobs. As noted above, there was little concern about drone technologies threatening employment, as one interviewee from the Steel Shop commented: "Yes, I can dispose of people, but they would be deployed elsewhere. There is always other work for them."

SteelCo.DE

Steel Co.DE employs approximately 13,500 people directly and is a significant employer in the region: an area renowned for its history of employment in heavy industry and mining. It is part of a multinational company, and industrial relations are strong, reflecting Germany's corporatist/coordinated economic model (e.g., Hall and Soskice, 2001). The research was conducted a year later than the Italian case study. The reason for the delay is significant, as it indicates the more proactive role of worker representation, in this case the works councils, in the corporative system of German industrial relations.

When the research project was introduced to workers at the German plant, the Works Council (WC) objected that it had not been consulted about the research fund application. WC members were concerned that conducting such an exercise without their approval had set a precedent that broke the terms of participatory decision-making. Failure to consult the WC also aroused suspicion that drones were being considered as a means to reduce the payroll, and concerns were, also, expressed at this point about excessive surveillance. However, because of data protection regulations on the current use of fixed CCTV cameras, our interviewees seemed not to view heightened surveillance as a risk. Other WC concerns related to drones colliding with workers/machinery, malfunctioning, and causing explosions in areas with flammable gases. Further meetings between the internal project leaders and the WC eventually led to a '*Betriebsvereinbarung'*—a factory agreement—setting out the permissible uses of UAVs in the plant, and establishing the difference between extended applications and new uses that would require new consultation and approval.

Attitudes toward innovation were generally quite positive at the plant, and by the time of the fieldwork, a drone had already been tested but not yet deployed for monitoring of piping systems, the original aim of the project at the German plant. The drone had been used to monitor, with a thermographic camera, the insulation of the hot blast stove, and the use of a drone to inspect roofs was, also, imminent at the time of the interviews. Interview discussions at the German plant focused primarily on the potential use of drones to monitor piping systems. Transport of various gases within the plant was facilitated by an intricate network of pipes varying in diameter and typically elevated several metres off the ground and bundled together in 'trails' of up to 20 pipes next to and on top of one another.

The frequency of pipe inspections was governed by a federal law, the '*Rohrfernleitungsverordnung*,' as well as by specific 'work instructions' (*Arbeitsanweisung*) issued by the company. Monitoring was always conducted according to regulations by two staff members, who would 'walk' the length of the pipe looking for signs of leakage, using binoculars, mobile lifters, or scaffolding to get closer to sites that warranted closer inspection. Visual clues, such as steam emissions, dripping moisture, and discolouration of the metalwork, were searched for, and specialized gas detection devices were also deployed. Suspected leaks, when accessible, were sometimes tested with reactive moisture sprays.

Scaffolding was normally required to facilitate the inspection of raised pipes, a time-intensive and costly exercise, as it had to be brought in by external providers. Our interviewees viewed such workers as being most likely to be replaced with drones. Further, like the roof workers at the Italian plant, the workers here also stressed the importance of embodied knowledge and the ability to 'filter out things that are less relevant.' This ability came with the accumulation of experience and the gradual training of the senses:

> Well, you develop a feel; for example, you develop a feel for noises that are related to leaks… But, someone who has not done that [and] walks along the same path … might not even notice the noise or not associate it with leaks because it is hissing everywhere in a steel plant, but you can develop a feel for this over time. (Service Division, Maintenance Engineer, Team Leader, SteelCo.DE)

Just like the Italian plant, the maintenance crews were, reportedly, short-staffed. Although drones could help with inspection of such a lengthy network of pipes, the team would still lack capacity for maintenance and repair work. Indeed, when some participants expressed the optimistic view that drones could free up labour time for actual maintenance and repair—'we employ a lot of people who do monitoring who could be better deployed in actually doing maintenance' (Service Division, Maintenance Engineer)—they may have been significantly underestimating the labour costs associated with UAV use.

When used for inspection, UAVs will also require separation of data collection from data analysis. Instead of the intuitive 'filtering' of sensory information by a worker in situ, the drone will capture and record a plethora of data, with workers then reviewing the information collected through the drone's camera and sensor technologies. One interviewee, who was familiar with use of the UAV to examine insulation integrity, stressed how time-consuming the analysis of the images proved to be:

> To inspect the hot blast stove, we went there, did all the flying and then went to the office to watch the film and analyse the state of the insulation. The flying time is rather short, but the time it takes to analyse the data is relatively large. (Service Division, Maintenance Engineer, Team Leader, SteelCo.DE)

Moreover, as the drones themselves cannot conduct maintenance and repairs, costs related to the use of scaffolding (and outsourced scaffolders) and lifters would only be saved by reducing 'false positives' (i.e., cases where closer inspection by repair teams revealed no actual problem), but drones would probably not allow such cases to be eliminated entirely.

Further, upskilling is needed to operate drones and analyze the collected data. First, operators are legally required to obtain a licence to fly a drone. Second, UAV-based digitalized gas pipe monitoring would also require new IT and data analysis skills. At this time, it is unclear who exactly will need training and how intensive such training needs to be (beyond that required for a licence), but HR interviewees noted that drone-related upskilling will not necessarily mean higher pay. Indeed, such opinions were corroborated by the comments of a different HR representative at the same plant who set out a broader strategy to integrate digital skills into initial training (i.e., apprenticeships), rather than continuing vocational training, in order to avoid pay negotiations with the relevant trade union, IG Metall, on digitalization and the likely creation of upskilled job roles and profiles.

Workers did, however, recognize the general benefits that might accrue from drone use to the individual, such as opportunities for upskilling and creating more value-added and highly skilled work through a wider range of identified potential drone uses beyond pipe monitoring. Such developments also raised questions for interviewees about how the use of drones would be organized, i.e., within existing teams, by new 'drone' specialist teams, or by outside providers. The last possibility might give workers and their representatives some cause for concern, should outsourcing of drone expertise become standard practice; the cost of purchasing and using drones (with related software and training needs) is significant, and this extra cost might make outsourcing an attractive proposition. The concerns were not directly voiced, but such outsourcing, of what might eventually become a key and routine function, raises questions about digital technologies and the disruption 'effect.'

Gains in worker safety were understandably prominent in discussions about other potential benefits from using drones at the German plant. Nonetheless, the anecdotal view was that repair work, not inspection, incurred the greatest risk of accident, and so in this respect the safety gains offered by drones might be less than assumed. Deployment of drones is subject to risk assessments mandated by the *German Occupational Safety and Health Act*, and there is acknowledgment that drone technology introduces new safety concerns (e.g., drones crashing from a high altitude, workers and machinery coming into contact with rotor blades, etc.). One engineer interviewee wondered whether a drone might endanger its operator because the latter, when working outside on uneven terrain, has to keep one eye on the drone and the other on the ground.

Discussion and Conclusions

Drones are a powerful and innovative technology with a multitude of potential applications, and their use is expanding within a range of sectors. For instance, they are being tested in construction for monitoring, inspection, and maintenance (Bogue, 2018), and in retail Amazon is trying them out for parcel delivery (e.g., Hern, 2016). To our knowledge, our paper provides the first discussion of their specific impact on the steel industry. It remains unclear whether they will ever be deployed systematically in that industry (and in other manufacturing sectors), and it remains unclear what their specific 'effects' will be. Indeed, such questions cannot be answered without attending to the specific social, economic, and legal relationships that will most likely shape their future use (in the steel industry and more widely).

Steel industry employers imagine that drones offer potential cost savings by reducing the need for labour and equipment to perform lengthy inspections of elevated sites. But workplace regulations and more broadly applicable legislation require that drone operators be trained and licensed, and drones cannot be flown without human control. Drones also collect large volumes of data that need analysis, which in turn requires new skills and, given the much greater volume of data collected by camera and new sensor technologies, a more desk-based expenditure of labour time. In other words, they are likely to incur new economic costs, and thus the commercial incentive to invest in their use is not immediately self-evident in the present circumstances and with regard to the aims of this particular RFCS project (i.e., to '*substitute*' workers). Overall, their possible applications are perhaps quite limited, i.e., mainly monitoring and inspection tasks. Just as limited is their potential to displace labour.

Indeed, workers at both sites described maintenance and repair teams as short-staffed. They thought that drones might reduce the labour performed on monitoring and inspection, but this reduction would be offset by redeployment of labour to other tasks, such as repair work. The overall number of employees would not be reduced. Drones may, however, by expanding the volume of data available, increase the number of identified defects; and some of those defects may require physical inspection in situ before they can be confirmed. In other words, drones might create more work. Given the discussed cost implications of investing in and deploying drones, it is difficult to imagine an already over-stretched workforce being given new resources at the same time that resources are being expended on supporting new digital technologies (Neef *et al.*, 2018). Maintenance teams complained about being short-staffed, but it is not difficult to imagine employers allowing this situation to continue. Further, employers may attempt to recoup the costs of deploying the new technology by reducing, as far as possible, the number of employees hired to perform inspections. The intensification of labour seems likely.

There is a broader point here. Whilst employers might imagine that digital technologies, like drones, could replace labour, or intensify use of labour, the workplace realities described by our interviewees make insertion of these technologies highly contingent. As it is, our interviewees remain relatively sanguine about the likely impact of drones on the company's need for labour. Despite the volatility of the industry and its myriad uncertainties, such optimism may well be informed by past experience (with what causes job losses and what does not) and may also convey an accurate view of the skill-related demands made by new workplace technologies, a view shared by some economists (Autor, 2015). Furthermore, it challenges narratives that treat digital technologies and the risks they present as inevitable and predetermined (Frey and Osbourne, 2017; Ford, 2015; Susskind and Susskind, 2015).

However, we should not forget that the workers' perspectives—and indeed their interests—are not identical to the employer's. A question for further investigation is whether the work that needs to be done in the eyes of the interviewees also needs to be done in the eyes of the company. How willing would the employers be to invest in the reskilling of their workforce, as opposed to replacing it from the publicly funded pool of more highly educated workers? This, too, is a question with significant ramifications for steelworkers like these, and one whose answer will inevitably reflect the specific economic structure of incentives, pressures, and rewards within which steel companies operate. On these questions it is important to reflect more widely on socio-political choices and the role of 'power' and 'interests' in shaping whether a technology is inserted into the workplace, and if so, how (see Lloyd and Payne, 2019).

Hence, we might reflect on worker representation and the difference between the strong corporate arrangements within *SteelCo.DE*, and the role of the Works Council to facilitate incremental integration of technological innovation (e.g., Maurice *et al.*, 1986; Hall and Soskice, 2001)—despite some evidence that management is seeking to exploit a current decline in IG Metall's bargaining power (see Dribbusch *et al.*, 2018), and management's cautious but 'productivist ethos' in Italy. The latter case suggests more short-term orientations associated with managerial predilections for centralized modes of control-based employment and unilateral decision-making, here based principally on "cost-benefit." The question is the extent to which those arrangements may weaken any ability to mobilize against emerging threats and risks, i.e., to prevent the use of drones as a tool of atomization and control (Pfeiffer, 2017. See Doering *et al.* (2015) for an industry-specific related discussion). The critical issue is twofold: the extent to which 'power' and 'interests' (Lloyd and Payne, 2019) allow for democratic debate over the insertion of 'digitalized artefact(s) of advancement' and over their 'effects'; and full representation of the role and power of different interests (Pfeiffer, 2017). Such arrangements will be reflected in any capacity to respond to *Industry 4.0* technologies and their 'effects' (Edwards and Ramirez, 2016).

By extension, we consider the needs and desires that gave rise to the technology, the social circumstances that shape its use, and the values, interests, and ideologies that define the parameters of the useful, the necessary, and the desirable (see Wacjman, 2018). Drones were originally developed for military surveillance and weaponry, and it is important to consider the extension to commercial and civilian uses of a technology that poses obvious threats to privacy and civil liberties (e.g., surveillance, dataveillance, and dignity at work. See Lupton, 2016). Workers have a natural interest in their work being something that enriches rather than degrades them, and such interest is attested by the frequency with which the interviewees highlighted gains in safety as strong justifications for the use of drones. Although minimum safety standards are a legal obligation, the employer sees improvement of the worker's physical wellbeing as a 'cost' and not as a gain.

As Marglin (1974) pointed out, productivity does not mean the same to the employer as it does to the employee. Greater work intensity, greater stress, greater risk of injury, greater mental and physical exhaustion—all of these are costs borne by the worker, who increases output at the cost of running a personal deficit in wellbeing. As long as the harm done to, and incurred by, the worker, is not paid for—in wages, insurance payouts, or legal claims—these costs to the worker remain for the employer a gain. Productivity rises if workers can be driven like machines, but Wacjman (2018: 168) points out that we are not hostages to the accelerating drive of digital technologies and must 'contest the imperative of speed and workaholism' and democratize the creation and use (of) these new technologies (see Spencer, 2018).

Machines can demoralize the worker in the changes they might bring to work and employment, and, of course, they may replace the worker too, and it is this latter trend that has historically led to warnings about the 'end of work' and a crisis of 'job scarcity' (Bowring, 1999). In this regard, it remains important to remind ourselves that whilst Marx showed sympathy for the machine-destroying acts of the Luddites, he was quick to point out that it was the private ownership of the machines—the capitalist relations of production—that was pauperizing the handloom workers, not the machinery itself (Marx and Engels, 1967). And yet, the warnings about digital technologies are perhaps no more than the latest in a succession of similarly voiced concerns over past innovations (e.g., Lloyd and Payne, 2019). Our workers recognize that it is not the machinery, itself, that threatens them. As such, like Thompson and Briken (2017: 258), we emphasize the need for discussions about digitalization and robotization to learn what workers experience and how their collective capacities might be exercised to shape how technology is used.

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SUMMARY

Digitalized Drones in the Steel Industry: The Social Shaping of Technology

New digital technologies are often framed as an inevitable and determining force that presents the risk of technological unemployment and the end of work (Lloyd and Payne, 2019). In manufacturing specifically, digitalization is referred to as *Industry 4.0*, a term that emerged in Germany as a central economic and industrial policy and has taken on a wider resonance across Europe (Pfeiffer, 2017).

In this article, we explore the workplace implications of a specific *Industry 4.0* innovation. We examine the insertion of drone technology—as a timely and topical example of industrial digital technological innovation—in the steel industry.

The article brings to debates on the digital workplace a discussion of the relationship between the material forces of production and the social relations within which they are embedded (Edwards and Ramirez, 2016). Drawing on interview data from two European industrial sites, we suggest that the increasing use of drones is likely to be complicated by a number of social, economic and legal factors, the effects of which are, at best, extremely difficult to predict. Introduced for their potential as labour-saving devices, drones seemingly offer a safer and more efficient way of checking for defects in remote or inaccessible areas.

However, whilst employers might imagine that digital technologies, like drones, might substitute, replace, or intensify labour, the workplace realities described by our interviewees make insertion highly contingent. We highlight several such contingencies, with examples of the ways that the steelworkers' interests differ from those of their employers, to discuss how the insertion of digital technologies will ultimately be shaped by the power, interests, values and visions prevailing in the workplace, as well as in the wider polity and public culture.

KEYWORDS: digitalization, industry 4.0, technological innovation, drones, industrial relations.

RÉSUMÉ

Les drones dans l'industrie sidérurgique: contours sociaux de l'avènement de cette technologie

Les nouvelles technologies numériques sont souvent présentées comme une force inévitable et déterminante qui engendre un risque de chômage technologique et de fin de travail (Lloyd et Payne, 2019). Dans le secteur manufacturier en particulier, l'avènement du numérique (*digitilization* en anglais) est appelée « Industrie 4.0 », un terme qui a, d'abord, émergé en Allemagne en tant que politique économique et industrielle centrale et qui a, ensuite, pris une résonance plus large à travers l'Europe (Pfeiffer, 2017). Dans cet article, nous explorons les implications sur le lieu de travail d'une innovation spécifique de l'Industrie 4.0. Nous examinons l'insertion de la technologie des drones — en tant qu'exemple actuel de l'innovation technologique numérique industrielle — dans l'industrie sidérurgique.

Se situant dans le cadre des débats sur le lieu de travail numérique, l'article introduit une discussion sur la relation entre les forces matérielles de production et les relations sociales dans lesquelles elles sont intégrées (Edwards et Ramirez, 2016). En nous appuyant sur les données d'entretiens de deux sites industriels européens, nous suggérons que l'utilisation croissante des drones sera probablement entravée par un certain nombre de facteurs sociaux, économiques et juridiques, dont les effets sont, au mieux, extrêmement difficiles à prévoir. Introduits pour leur potentiel en tant que dispositifs permettant d'économiser du travail, les drones offrent apparemment un moyen plus sûr et plus efficace de vérifier les défauts dans les zones éloignées ou inaccessibles.

Cependant, alors que les employeurs peuvent imaginer que les technologies numériques, comme les drones, sont à même de remplacer, d'éliminer ou intensifier le travail, les réalités des lieux de travail décrits par nos interviewés révèlent une insertion très contingente. Nous mettons en évidence plusieurs de ces éventualités, avec des exemples de différences entre les intérêts des métallurgistes et ceux de leurs employeurs, dans le but de discuter de la manière dont l'insertion des technologies numériques sera finalement façonnée par le pouvoir, les intérêts, les valeurs et les visions qui prévalent sur les lieux de travail, ainsi que dans le système politique et la culture publique au sens large.

MOTS-CLÉS: numérique, industrie 4.0, innovation technologique, drones, relations industrielles.