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

Abstract: In this paper we draw on interview data from a project exploring the insertion of digital technology within 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 social shaping of technology perspectives to challenge overly determinist narratives. We discuss how the insertion of digital technologies will ultimately be shaped by the power, interests, values and visions prevailing within the workplace, as well as the wider polity and public culture. In this way, we bring to debates on the digital workplace a discussion of relationship between the material forces of production and the social relations within which they are embedded.

Key Words: Digitalisation, Industry 4.0, Technological Innovation, Drones, Industrial Relations.

1. 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 quality of jobs (Brynjolfsson and McAfee, 2014; Schwab, 2016). And yet, as Lloyd and Payne (2019) suggest, many accounts of new technologies are speculative, heavy on anecdote and lack a fuller understanding of what their insertion in the workplace will mean for work, workers, and society more generally (see Spencer, 2018).

Digitalisation within manufacturing is often referred to as *Industry 4.0*, a term that emerged from Germany as a central economic and industrial policy, which has taken on a wider resonance across Europe (Pfeiffer, 2017). The process of digitalisation within manufacturing signals progression from epochs of steam, electrification, computers and automation to 'cyber-physical systems' of production configured upon digital networking systems and the centrality of 'big data' for 'smart factories' (Briken et al. 2017). Specific digital innovations with the potential for use within 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 the use of drone technologies for generating data on maintenance and production (Naujok and Stamm, 2017). For the steel industry, as the focus for this paper, digitalisation is the most recent feature of innovation aimed at achieving a 'business model transformation' for greater efficiencies and building global competitiveness (Naujok and Stamm, 2017; Neef et al. 2018).

With such developments in mind we explore the potential impact of the insertion of a particular piece of digitised technology within the steel industry: unmanned aerial vehicles (UAVs), more commonly known as drones. As a topical and timely example of digitised industrial robotisation, 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 within the workplace is often viewed as inevitable and such technologies are treated as a determining force that society can only respond to 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 within industry can be determined in advance, and argue that their use will ultimately be shaped by the interests, values and visions prevailing within the workplace and 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 within 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, involving two steel plants based in Germany and Italy, and aimed at "*substitut(ing) men* [sic] *in complex and expensive operations… [with drones]… related to the monitoring, maintenance and safety of steel plant infrastructures*". In the administering of these functions our data suggest that the use of drones in the near future is likely to be influenced by wider regulatory contexts (e.g. European legislation, health and safety regulations, data protection) and the specific contours of work, employment and representation within the sector. Our analysis offers an account that acknowledges the potential for workplace (and societal) disruption caused by digital technologies, but also draws attention to social shaping of technology perspectives to challenge overly determinist narratives (Wacjman, 2018).

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

2. Technology, Work and Society

In debates about the impact of technology on society, two opposing perspectives are commonly delineated. The first perspective emphasises 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 de-natures our bodily relationship to the world (Gorz 1989; Postman 1993; Bowring 2003).

Related discussions of technological determinism that are focused specifically on the insertion of technologies within the workplace, view technology as hardware – equipment, instrument or machine – and understand it as an objective and external force that directly impacts the organisational aspects of work. Such literatures position technology and its immanent characteristics as an independent factor, which wholly influences human interaction in the workplace, and determines the organisational 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 Marx and Adam Smith, and the view that technical progress follows development along the single path of efficiency (see Edwards and Ramirez 2016; Spencer 2018).

The ‘social shaping of technology’ (MacKenzie and Wajcman, 1985) is a second perspective which 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 within the capitalist relations of production more broadly and, more specifically, 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 and 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 determinist. Indeed, new digital technologies are often framed as an inevitable and determining force, which present the risk of technological unemployment and end of work (Spencer, 2018), particularly for those employed to routine manual and cognitive tasks (Frey and Osbourne, 2013). Society responds by addressing the threats to jobs posed by these nascent technologies, which includes ideas for taxing robots and introducing a universal basic income, but typically focuses 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 digitised ‘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 determinist 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 digitalisation 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 ask about the 'effects' of *Industry 4.0* and digital technologies – technology about which we can only speculate, not least because it is at the incipient stage and, within the workplace, represents a high level of discontinuity. The point here is that analysis of the 'effects' of 'new, new technologies' and the particular properties of, for example, drones will help inform collective responses on whether to embrace or resist the technology (Edwards and Ramirez, 2016: 99). This begins to give space for the regulation of capitalist social relations and workers' capacity (where it exists) to exercise collective power at the workplace, and thus shape technology impacts on the material realities of their work and employment.

This is an important dimension of analysis, which begins to foreground the role of 'powers' and 'interests' in shaping whether and how *Industry 4.0* technologies are inserted in 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 concerned with the relationship between technology, society and work, but we lay the foundations for the discussion of our interview data and emergent questions on the 'inevitability' of digital technologies for work, employment and society.

3. Methods

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

- *Social requirements* e.g. safety and surveillance and 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 e.g. new means of inspecting roofs, 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, from the knowledge and perspective of steelworkers, the potential benefits and risks of drone technology as it might be utilised in the industry.

Case Site	**Drone inspection use**	**Interviews**	**Sections Covered**	**Professions Covered**	**Position Covered**
SteelCo.IT	Roof Chimney	4 groups 12 workers	• Galvanising • 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

Table 1: List of Interviews

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, system engineers to maintenance engineers. The interviews were conducted with the aid of a translator supplied by the company, and this was supplemented by a tour of the plant. In 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 participant was from Human Resources, and two worked in another nearby plant owned by the same company. The interviews were conducted in German by a bi-lingual member of the research team and involved team leaders, section leaders and operators, and their technical roles ranged from maintenance engineers to central administrators. Here, too, the researchers were given a tour of the plant, including sites where a drone had been tested and deployed as part of the project.

4. The European Steel Industry

The specific context for our discussion of digitised drone technologies is the European steel industry. It is an industry that has experienced significant processes of privatisation, rationalisation and restructuring over recent decades, all of which have carried considerable implications for the workforce. Whilst the industry has high levels of worker representation (Beguin, 2015), it has proved difficult for worker representatives to defend against substantial cuts to the workforce. The industry workforce has 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 organised (e.g. high-performance work systems [HPWS] are now widely utilised) and more highly skilled and qualified (e.g. Bacon and Blyton, 2000; Stroud, 2012). This detail is important because it establishes the context within which the steel industry workforce experiences processes of innovation.

There is a constant focus on innovation across the European industry as it struggles to remain competitive. Whilst not all innovation is technological e.g. the introduction of team working to the industry during the 1980s and 1990s signalled innovatory efforts to improve productivity and performance at an organisational level (Bacon and Blyton, 2000), the principal focus of innovation today is on the technological transformation of the industry driven by digitalisation. Digitalisation is not the simple transfer from analogue to digital data and documents, but configured upon the networking of business processes, efficient interfaces and integrated data exchange and management (Bogner et al, 2016). Within the steel industry specifically, the intelligent combination of process automation, information technology and connectivity enable the digitalisation of steel production to go far beyond the conventional automation of industrial production (Murri et al, 2019). The drone technology we discuss represents one such example of innovation in this direction.

5. Inserting Drone Technology in the Steel Industry

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

5.1 SteelCo.IT

The Italian steel plant is one of the largest steelworks in Europe – a capacity of 10 million tonnes and an on-site workforce of around 20,000 (twelve thousand directly employed). It has been mired in some controversy over past decades (mainly related to pollution) and since our visit has been acquired by a large multi-national competitor. Through our access negotiations with the plant it became clear that relations between management and trade unions is fraught, which seems to reflect the more general state of industrial relations in Italy (e.g. Hyman, 2001; Culpepper and Regan, 2014). Interviewees noted, however, that despite such difficulties, on-site trade unions would always be consulted about the introduction of new technologies, including drones. And yet, at the time of the interviews, it became clear that the aims and objectives of the RFCS-funded project had not been widely disseminated 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 in 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; and 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 members of the roof inspection team had considered the use of drones for monitoring roofs before the interview, but all appeared positively disposed to their deployment. 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 drones were used by each section's own civil works specialist for pre-repair inspection.

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

From the perspective of the roofing team, whether the team – currently numbering 26 personnel for the whole plant – expands or contracts appears to be ultimately dictated by the importance management attribute to roof maintenance, not to 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 viewed to be those 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 possess sufficient experience of 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; 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, in relatively high temperatures, in toxic air and in darkness – was for most 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. [Galvanising, Maintenance Engineer, Section Leader, SteelCo.IT]

But better safety was not believed by the workers to be a priority of the managers of the plant. 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 dislike changes as '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 galvanising line area safety coordinator pointed out that cameras were already widely used in the area – though for legal (i.e. data protection) reasons these were trained on the equipment not the people – which perhaps also explains why workers at the plant 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 over the introduction of new technology.

Data analysis and interpretation are also highly-skilled and time-intensive activities requiring further labour power and skills investment to be incorporated, from the interviewees' perspective, within existing team-working 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 [specialised] training … [Cold Rolling Mill, Maintenance Engineer, Section Leader, SteelCo.IT]

Perhaps surprisingly – given some recent redundancies – the general 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. There was little concern of 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."

5.2 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 heavy industry and mineral extraction employment. It is part of a multinational company and industrial relations are strong, reflecting Germany's corporatist/coordinated model traditions (e.g. Hall and Soskice, 2001). The research was conducted a year later than the Italian case and 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. Members of the WC 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 a suspicion that drones were being considered as a means of reducing the payroll, and there were also concerns expressed at this point regarding 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 towards innovation are generally quite positive at the plant and by the time the fieldwork was conducted a drone had already been trialled, but not deployed for pipeline monitoring, the originally proposed focus 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 the interviews were conducted. Interview discussions at the German plant focused primarily on the potential use of drones to monitor pipelines. The 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 bundled together in 'trails' of up to 20 pipelines next to and on top of one another.

The frequency of pipeline inspections is governed by a federal law, the '*Rohrfernleitungsverordnung'*, as well as specific 'work instructions' (*Arbeitsanweisung*) issued by the company. Monitoring was always conducted according to regulations by two members of staff, who would 'walk' the length of the pipeline 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 specialised 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 bought in from external providers – as in Italy it was these workers that were viewed by our interviewees most likely to be substituted by 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' that comes 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, and although drones could help with the inspection process of such a lengthy network of pipes, the team would still be lacking capacity for maintenance and repair work. Indeed, the optimistic view expressed by some participants 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) – may significantly underestimate the labour costs associated with UAV use.

UAVs deployed for inspection purposes will also necessitate a separation of data collection from data analysis. Instead of the intuitive 'filtering' of sensory information by the worker in situ, the drone will capture and record a plethora of data, with workers then reviewing the information collected through the camera and sensor technologies of the drone. One interviewee with knowledge of the use of the UAV to examine the integrity of the insulation 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. where closer inspection by repair teams revealed no actual fault), but drones would probably not allow these cases to be eliminated entirely.

Further, the operation of drones and analysis of the data generated would require upskilling. First, it is a legal requirement for operators to obtain a licence to fly a drone. Second, the UAV-based digitised gas pipeline monitoring would also require new IT and data analysis skills. At this moment in time, it is unclear who exactly will need training and how intensive such training needs to be (beyond that required for a license), but HR interviewees noted that drone related upskilling will not necessarily mean increased remuneration. Indeed, such perspectives are further reflected in the comments of a different HR representative at the same plant who set out a wider strategy to integrate digital skills within initial training provision (i.e. apprenticeships), rather than continuing vocational training, in order to avoid pay negotiations with the relevant trade union, IGMetall, on digitalisation and the likely creation of upskilled job roles and profiles.

The general benefits that might derive from drone use to the individual, such as opportunities for upskilling and creating more value added and high skilled work, was however recognised by workers in relation to the wider range of potential drone uses identified beyond pipe monitoring. Such developments also raised questions for interviewees of how the use of drones would be organised i.e. within existing teams, new ‘drone’ specialist teams or, indeed, outsourced provision. The latter might give workers and their representatives some cause for concern, should outsourcing drone expertise become standard practice; the cost of purchasing and using drones (with related software and training needs) is significant and this might make outsourcing an attractive proposition. The concerns are not directly voiced, but the issue of outsourcing 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 of using drones at the German plant. Nonetheless, the anecdotal view was that repair work, not inspection, carried the greatest risk of accident, and so in this respect the safety gains offered by drones might be less than assumed. The deployment of drones is regulated by risk assessments mandated by the German Occupational Safety and Health Act, and there is acknowledgment that the technology introduces new safety concerns (e.g. drones crashing from height, workers and machinery coming into contact with rotor blades, etc.) and one engineer interviewee pondered whether drones themselves might put the operator at risk of accident, since the latter, when working outside on uneven terrain, had to keep one eye on the drone and the other on the ground.

6. 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 e.g. in construction there are experiments with regard to monitoring, inspection and maintenance (Bogue, 2018) and in retail Amazon is trialling parcel delivery (e.g. Hern, 2016). To our knowledge, our account is the first to discuss their specific impact on the steel sector. Whether they will be deployed systematically in the steel industry (and other manufacturing sectors), and with what specific 'effects', is unclear (see Edwards and Ramirez, 2016). 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).

For employers in the steel industry, it is imagined 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 wider legislation require that drone operators be trained and licenced, and drones cannot be flown without human control. The data collected by drones also needs to be analysed, requiring new skills and, given the much greater volume of data collected by camera and new sensor technologies, more desk-based expenditure of labour time. Drones are likely to incur new economic costs, in other words, and thus the commercial incentive to invest in their use is not, in the present circumstances and with regard to the aims of this particular RFCS project (i.e. to *'substitute'* workers), immediately self-evident. Overall, as an application their scope for use is perhaps quite limited i.e. mainly monitoring and inspection tasks, with the potential to displace labour limited, too.

Indeed, workers at both sites described maintenance and repair teams that were short-staffed and envisaged that drones might reduce the labour spent on monitoring and inspection, but this would only allow for labour to be redeployed elsewhere e.g. for repair work and not reduce numbers. 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 i.e. 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 of being short-staffed, but it is not difficult to imagine that employers would allow this situation to continue. Further, they 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 would certainly seem likely.

The broader point here is that whilst employers might imagine that digital technologies, like drones, could replace (or intensify) labour, the workplace realities described by our interviewees make insertion 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 outlooks in relation to these new digital technologies may well be informed by the past experience of the workers (on what costs jobs and what does not) and it may also convey an accurate view of the skill-related demands made by new workplace technologies, a view shared by some economists (Autor, 2015). What it also offers is a challenge to the narratives that treat digital technologies and the risks they present as inevitable and determining (Frey and Osbourne, 2017; Ford, 2015; Susskind and Susskind, 2015).

However, we should not overlook the fact that the workers' perspectives – and indeed the workers' interests – are not identical to those of the employer, and 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, is a question requiring further investigation. How willing the employers would be to invest in the reskilling of its own workforce, as opposed to replacing it using the publicly funded pool of more educated workers, is also a question with significant ramifications for steelworkers like these, and one whose answer will inevitably reflect the particular 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 in 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 the incremental integration of technological innovation (e.g. Maurice et al., 1986; Hall and Soskice, 2001) – despite some evidence that management seeks to exploit a current decline in IG Metall's power resource (see Dribbusch et al. 2018) – and management's cautious but 'productivist ethos' in Italy. The latter suggests more short-term orientations associated with managerial predilections for centralised 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 mobilise against emerging threats and risks i.e. prevent the use of drones as a tool of atomisation and control (Pfeiffer, 2017. See Doering et al. (2015) for an industry specific related discussion). The critical issue being the extent to which 'power' and 'interests' (Lloyd and Payne, 2019) allow for democratic debate on the insertion of 'digitalised artefact(s) of advancement' and their 'effects', and that the role and power of different interests are fully represented (Pfeiffer, 2017) – any capacity to respond to *Industry 4.0* technologies and their 'effects' will reflect such arrangements (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 the extension to commercial and civilian uses of a technology which poses obvious threats to privacy and civil liberties needs to considered with care (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 the frequency with which gains in safety were highlighted by interviewees as strong justifications for the employment of drones is testimony to this. However, while minimum safety standards are a legal obligation, from the perspective of the employer, improving the physical well-being of the worker is a 'cost' not a gain.

As Stephen Marglin (1974) pointed out, what counts as productivity to the employer is not the same as what it means to the employee. Greater work intensity, greater stress, greater risk of injury, greater mental and physical exhaustion, are, in other words, costs borne by the worker, who increases the output by running a personal deficit in wellbeing. As long as the harm done to, and by, the worker, is not paid for – in wages, insurance 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) identifies that we are not hostages to the accelerating drive of digital technologies and must 'contest the imperative of speed and workaholism' and democratise the creation and use (of) these new technologies (see Spencer, 2018).

Machines can demoralise workers in the changes they might bring to work and employment, and, of course, they may replace them too, and it is this latter trend which 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 – capitalist relations of production – which was pauperising the handloom workers, not the machinery itself (Marx and Engels, 1967). And yet, the warnings over 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 recognise that it is not the machinery itself that threatens them. As such, like Thompson and Briken (2017: 258), we emphasise the need for discussions of digitisation and robotisation to reflect what workers experience and how their collective capacities might be exercised for shaping how technology is used.

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