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DISCUS PROJECT

Digital Transformation in the Construction Sector: challenges and opportunities

**Digitalisation and industrial relations in the Construction sector:
national case studies in six European Countries**

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Introduction: the DISCUS project

This comparative analysis of national case studies is part of the project DISCUS (Digital Transformation in the Construction Sector: challenges and opportunities), a European Union co-funded research project (DG Employment, Social Affairs and Inclusion, VS/2019/0078).

The DISCUS project aims to analyse and to strengthen the role and contribution of innovative industrial relations structures, including social dialogue, in responding to the major challenges and opportunities brought by digitalisation and technological changes in the construction sector to guarantee better environmental and social conditions for the workers and citizens of the European Union.

This report presents the main finding of the comparative analysis of the case studies carried out in the country partners in order to analyse concrete experiences of industrial relations coping with digital and technological changes in the construction industry across different levels and territories. Initially, it describes the methodology and an overview of the national case studies. The following paragraphs presents the analysis of the work organization and socio-technical models; the impacts on employment in terms of skills and professions; the working conditions, considering the occupational health and safety and some preliminary consequences of the Covid-19 pandemic; the work relations, with a focus on the workers' participation, cooperation and coordination; the role of industrial relations and social dialogue, especially considering the trade unions. Finally, conclusions try to summarize the main evidences to prospect some key analytical and empirical observations to better address the overcoming digital innovations.

1. Methodology

In order to explore these processes, three different case studies have been undertaken in each country partner of the project (Italy, Belgium, Bulgaria, France, Germany, and Spain).

The case studies try to consider the whole spectrum of digital innovations and their effects along the entire value chain. In each country case studies were selected with the aim to cover all the main digital technological innovations (BIM, robot and automation, software and ICT tools) considering big and small companies, different phases of the value chains (on the building site and off-site), different sectors of the construction industry (private and public building, wood, materials) (table 1).

The methodology is based on a “triangulation” of data sources: direct observation, documentary analysis and qualitative survey tools based on in-depth interviews with “privileged-witnesses” considering different actors involved in these processes: workers and workers' union representatives; employers and representatives of employers' organizations; experts; professional associations.

The specific analytical dimensions of the semi-structured questionnaire used to analyse the impacts of digitalisation on multiple levels are:

- description of the company and main characteristics of the case (activities, its environment, actors);
- main innovations that characterize the case study;
- impacts of the digitization process on work organization and value chain;
- impact of new technologies on professions, skills and recruitment;
- relationship between innovations and quality of work life;
- drivers and barriers of the digitalization processes;
- impacts of new technologies on social dialogue and the new role of industrial relation to tackle the impact of digitalization;
- impacts of Covid-19 in the digitalisation processes (as a dimensions added with the start of the pandemic emergence in 2020).

1.1. National case studies: an overview

This section presents the main features of each national case study. For an exhaustive reading, reference can be made to the national reports (table 2).

Belgium:

- multinational company, world leader in the construction, service and maintenance of transport infrastructures, with a focus on a corporate entity specialized on the colossal projects with the aims to ensure coordination among the activities, with a specific department to implement BIM projects.
- two sister companies, they operate in the wood construction sector, more specifically in the timber frame constructions market and they are considered to be among the most advanced in their sector in Belgium. Both companies are part of a larger group dedicated to the research,

development and commercialisation of the robotic production lines at large scale. Digitalisation by robots is a key topic. Overall, the two sister companies employ around 100 persons.

- a general construction company, a family business, with 60 blue-collar workers and around 25 white-collar employees. In 2020 it decided to switch to a just-in-time production system with the aim to manage production flows based on demand and not on supply, with a standardization of wood materials and activities and an increased use of machineries and robots (but not BIM).

Bulgaria:

- an European-based technology group for construction services, leader in innovation and financial strength. Their services span all areas of the construction industry and cover the entire construction value chain. In 2018, the company established the business unit 3D Mapping Services as the organisation for a new business field. The entity offers services with innovative measuring systems for object surveying, such as drones and mobile laser scanning, internally and on the external market. The entire value chain – from data capture to 3D data analysis – is to be done digitally, with the use of BIM.
- a company specialized in advising on commercial and technical issues related to the products offered for construction, automotive, shipbuilding, and other sectors, with over 30 highly qualified employees. The BIM corporately developed projects are provided to clients and designers, with a dedicated 3-D center for automated building construction, to provide robots, automations and other technologies developed by their own innovation and production centers.
- specific case studies are focused on three different field: BIM application (used in both companies); smart-devices on site building and smart-factory off site building (considering the company specialized in advising on commercial and technical issues).

France:

- a medium group, with 150 employees, comprising a construction company (parent company), a property development company and a demolition and asbestos removal company. It operates as a general contractor but also, and increasingly, on design-and-build contracts, global contracts under which the company offers its clients (project owners) a turnkey solution, from the design of the construction to its delivery, with an high specialization on the application of BIM and the use of several technologies.

- a small independent company with 19 employees, it operates as subcontractor for large companies in the construction sector and it has since evolved to respond directly to tenders for work issued by the owners. It is primarily a user of BIM models designed and implemented by others, in particular the project managers, and there is an high orientation towards innovation.

Germany:

- building materials industry, where BIM is assuming a growing relevance in the recent years
- company of the pre-fabricated house construction sector, specialized in private family buildings, characterized by industrial models of the work flow for production off-site and assembly on-site, where digitalisation is adopted especially through automation and the progressive use of machines and the recent introduction of robots. The company currently employs more than 700 people for the sale and manufacture of prefabricated houses, including around 300 production and 250 administrative employees at the production site.
- Germany's multinational company, part of Grupo ACS, one of Europe's largest construction companies, with a focus on its role as a competence center for digital construction planning (offering BIM services within the company and also for external customers, oriented towards the implementation of a Group-wide BIM standard, and with various other digital transformation processes.

Italy:

- a engineering company specialized in structural and architectural design, leader in the application of BIM , considering different projects (urban location and gulf terminal) chosen with the aim of giving an overview of the multiple implications of BIM applications in relation to overall value chain of the construction industry.
- a construction site in a city in the North Italy, characterized by high fragmentation, with a focus on the BIM and the application of smart-devices at site level as a key field to understand the innovation, as a result of various innovations applied in all the production areas along the value chain, with a direct impact on the relations among several professional profiles.
- a company in the wood industry, a pioneer in the design and production of 100% ecological panels, a leader company at global level in the processing and transformation of recycled wood, based on a circular economy process, with high investment in innovation, many technologies

at industrial level and the adoption of a modular software system, with an impact on administrative and management processes. The Group, with various sites in Italy and abroad, currently employs around 1,500 people.

Spain:

- a multinational business group of construction, development and operation of infrastructures and civil buildings, with a relevant level of innovation and the adoption of various digital technologies, as BIM.
- medium company focused on promotion and construction of buildings, with the use of many technologies and a high degree of innovation in the construction process such as automatization of tasks, off-site prefabrication, BIM, own software and digitalisation of administrative tasks.
- a large business group dedicated to construction, with the use of technological innovations, strictly related to the industrialization of the production and pre-fabrication process, as well as other additions such as the gradual introduction of BIM, digitization of processes and tasks, incorporation of digital management software, use of applications and digital devices.

Table 1. National case studies: main aspects

Country	Case study	Dimensions Small (<50) Medium (50-200) Big (>200)	Main digital innovations analyzed	Off-site / On-site Analytical focus	Construction Sub-Sector
Belgium	Multinational company	Big - Multinational	BIM	Off-site	Road, Materials, Rails
	Two sister companies	Medium	Robots, automation	Off-site / On-site	Wood - Building
	Family business company	Medium	Software and ICT	Off-site / On-site	Private and Public Building
Bulgaria	European technology group	Big – Multinational	BIM	On-site	All areas of construction industry
	Company specialized in commercial/technical issues	Small	BIM, robots, automation	Off-site	Construction and other industrial sectors
France	Medium group	Medium	BIM	Off-site / On-site	Construction, demolition and asbestos removal
	Small independent company	Small	BIM	Off-site / On-site	Roofing, waterproofing and cladding
Germany	Building materials industry	High fragmentation	BIM	Off-site	Building materials
	Prefabricated house manufacturer	Big	Robots, automation	Off-site / On-site	Private building
	Multinational company	Big - Multinational	BIM	Off-site / On-site	Building and civil engineering
Italy	Engineering company	Medium	BIM	Off-site / On-site	Civil engineering
	Construction site	High fragmentation	BIM	On-site	Building
	Company in the wood industry	Big	Robots, automation	Off-site	Wood - Materials
Spain	Multinational business group of construction	Big - Multinational	BIM	On-site	Infrastructures and civil buildings
	Medium company	Medium	BIM	Off-site / On-site	Private and civil building
	Large business group dedicated to construction	Big - Multinational	BIM	Off-site / On-site	Private Building

Table 2. National case studies: national reports

Country	Case study	National Report
Belgium	Multinational company	Wuidar S., Colas Group and the “Tram of Liège” project, National Case Study Report, 2, Belgium, Discus Project, 2021
	Two sister companies	Franssen M., MOBIC/SCIDUS, National Case Study Report, 1, Belgium, Discus Project, 2021
	Family business company	Pere M., Picard Construct, National Case Study Report, 3, Belgium, Discus Project, 2021
Bulgaria	European technology group	WETCO, National Case Studies report, Bulgaria, Discus Project, 2021
	Company specialized in commercial/technical issues	
France	Medium group	Teissier C., BIM in SMEs – a reality?, National Case Studies report, France, Discus Project, 2021
	Small independent company	
Germany	Building materials industry	Mühge G., Harbecke T., Building materials industry and the Bien-Zenker company, National Case Studies report, Germany, Discus Project, 2021
	Pre-fabricated house manufacturer	
	Multinational company	Mühge G., Harbecke T., Hochtief, National Case Studies report, Germany, Discus Project, 2021
Italy	Engineering company	Rugiero S., Di Nunzio D., De Angelis G., Brachini N., National Case Studies report, Italy, Discus Project, 2021
	Construction site	
	Company in the wood industry	
Spain	Multinational business group of construction	Cruces Aguilera J.C., de la Fuente Sanz L., National Case Studies report, Spain, Discus Project, 2021
	Medium company	
	Large business group dedicated to construction	

2. Digitalisation and work organization: socio-technical models

The analysis of the case studies shows some general considerations about the relation between digitalisation and the work organization models, considering three main typologies of digital innovations: BIM, robots and automation, software and ICT tools. Digital transformation affects all phases of the constructive process and the whole network of the value chain. In particular, all the technologies have **impacts on the organizing models**.

First, it is appropriate to highlight the close relationship between digital technologies and the organization of work by considering the processes of standardization and rationalization of work that fuel the affirmation and strengthening of a wide lean construction process.

- **BIM** is a socio-technical organizing model to support the management of actors and activities in the construction projects, considering two related dimensions: relations (with the aim to ensure coordination) and technical aspects (considering all the activities, materials, tools, time, space, etc.).

It is an evolution and adaptation of the lean production and of the Total Quality Management System for the Construction sector. It aims to reduce waste, to improve coordination, to increase the rationalization and government of the projects, to guarantee a modular standardization to satisfy a high degree of flexibility for highly diversified construction products.

- Use of **robots and automation** is specially focused on the big technologies to execute heavy tasks (as the machinery means) and on the repetitive tasks. The adoption of robots and automation is associated to a growing relevance of the pre-fabrication phase, even if they are increasingly adopted also at building site level. However, at a general level, robots and automation are strictly related to a standardization of the working process and materials. Also, the analysis shows the growing relevance in the use of wearable tools and personal ICT tools, with the aim to facilitate the heavy and complex tasks.
- Use of **software and Information and Information and Communications Technologies (ICT)** is a transversal digital innovation, inevitably related both to BIM and the use of robots and automation, as well as to the general production process. Software is applied for administrative and management procedures as well as for the development and monitoring of the projects by the acquisition of data and information by ICT and communication tools, sensors, drones, etc. Software aims at improving the standardization process as well as the opportunity of a continuous

control and review of the project. Moreover, the introduction of digital innovation sometimes favors acceleration and interconnection with other innovative technologies.

The general trend is toward an association of these digital innovations with the aim **to standardize the process and to improve the communication and control among all the phases of the value chain**, in highly fragmented, flexible and dynamic processes, with a key role of the core companies.

SPAIN - Case studies - Conclusions

Digital transformation consists of the incorporation of different kinds of technologies in the constructive process. When companies consider digital change, they try to include all technology (including, for example, BIM, management software, applications on digital devices -tablets and smartphones- and precastings). [...] Digital transformation would affect all phases of the constructive process. However, nowadays it has an even impact on the value chain. Studied cases have shown that when companies incorporate technology into their productive activities, their impact is higher in the design and planification phases, rather than on construction “on site”. However, the construction phase is also impacted.

Cruces Aguilera J., de la Fuente Sanz L., Spain Case Studies, Report, 2021

On the construction firm side, the development of a “**lean construction site**” push to assume an industrial posture. By this way standardization needs to cope with the traditional approach of the Construction sector based on the unicity of each building with an orientation towards the production of **prototypes** of the artefacts and buildings.

FRANCE – Case studies A - Medium group –

As a provisional conclusion, it seems to us that it makes sense to quote the former President of the National Plan for the Digital Transition of the Building Industry interviewed during the first phase of the project: “If we are indeed able to deploy a digital model, from the project owner up to the selection of the companies, if we go in this direction, then this will increase the capacity to define and order in advance what we want. From this point of view, digital can help to solve potential difficulties in the factory rather than on the building site and therefore prefabrication and digital go hand in hand, potentially even leading to the disappearance of assembly functions on the building site in favour of robots, building on site. There is worldwide research on this subject but in France, buildings are still mostly prototypes, unique non-standardized parts, and we therefore envisage here another stage of evolution than BIM, a real standardization of construction, which is still far from being achieved”.

Teissier C., BIM in SMEs – a reality?, National Case Studies report, France, Discus Project, 2021

Organisational innovation due to digitalisation implies a cultural revolution to transform a craft sector into an industrial sector, based on rationality, effectiveness, strategies, reduction of unexpected events and forecasts.

The implementation of **new management systems**, based on constant monitoring and full control of all activities inside and outside the company, planning future activities and investments, measurability of results, leads to a potential increase in the complexity of work organisation, in the sense that new actors now play a role in the coordination of tasks. This situation is likely to blur the hierarchical line, as the worker must now respond not only to the orders of his or her department head, but also to those of the client, business partners, etc. This evolution also claims for a new organizational and management culture as opposed to the analogical one typical of the construction sector.

France – Case A - Medium group – General contractor

The point concerning the changes in the organisation of work generated by the use of BIM that was most emphasised during our interviews is the coordination between different companies working together on a site. This is probably the major change brought about by the development of BIM, which leads us to see the latter as a tool, which, far from being merely technological, should lead to increased cooperation between the various companies working on a site.

Teissier C., France Case Studies, Report, 2021

The analysis of the case studies shows that there are different ways to actualize these **relations between technology and organizing models**: as a **mere tool in itself** for the execution of tasks, as a tool to improve productivity but also **to protect workers**, in a **human-centric way** considering the employees as the central actors of innovation with a broader perspective of innovation.

Germany – Case studies - Conclusions

It also became clear that, in addition to the technological drivers, a wide-ranging concept has been launched to accompany employees on the path of digital transformation and protect them from negative consequences. To this end, the company has developed a comprehensive range of training courses and the company's social partners have concluded agreements that regulate the implementation of digital processes and protect the rights of employees. HOCHTIEF is particularly committed to managing the digital transformation in a human-centric way, placing employees at the center. The company is thus pursuing the approach of a “toolscenario” (cf. Windelband/Spöttl 2011), which sees employees as central and shaping actors and in which technology serves as a tool for people.

Mühge G., Harbecke T., Germany, Case Studies, Report, 2021

2.1. Socio-technical model for the construction value chain

Digitalization not only affects many aspects of work, but also changes the interactions between all stakeholders, throughout the life cycle, across all value chains in the construction sector.

In fact, digitalisation permeates every aspect of the construction sector considering the **whole construction production cycle** (material production, construction, maintenance, upgrading, dismantling, reuse), **each internal sectoral division** (building, wood, materials), **small and big companies, employed and self-employed workers, high and low-skilled professions.**

The way of working induced by digital innovations (based on the sharing of data and information, flexibilization and standardization of the working processes) tends to reorder the value chain and its relationship with subcontractors with a strengthening of the needs for networking and coordination, with not univocal impacts.

Bulgaria - Case C - Smart-factory off site building

The company uses digital programs and tools (like SAP) that allows the optimization of the work processes, procedures and phases. This time saving tools make visible the whole implemented project, or the main details that has to be accomplished by the employees. The digitalised work area has positive Impact on the dimension of flexibility of the working process, on the standardization of the working process and enables coordination between team members. Very important issue is that the digitalised process of the product elaboration is accessible also for the other actors of the value chain- i.e. the client, the trading consultant etc.

WETCO, Bulgaria, Case Studies, Report, 2021

The implementation of the digital tools takes time and requires adaptability on the part of workers who have to learn new working methods, but also to approach the value chain in a different way: **moving from a stratified approach of the value chain to a more synchronic and collaborative one.** **Coordination between companies** along the value chain is a big challenge for the construction sector as it is strongly fragmented. For the building materials industry, the main goal is to be involved in the value chain at an early stage and thus to be involved in all planning stages from the beginning. For example, considering the BIM cases, if subcontractors are not incorporated into the BIM platform, the risk of transferring pressure of deadlines and job rotation may be increased.

The general trend is an improvement of the industrialization of the sector by the digitalisation and the mix of these two factors push toward the affirmation of **lean construction models** in the sector.

Moreover, working with BIM can also change the relations along the value chain with a long-term perspective if we consider the opportunities to storage data in 3d models and the use of these information by other companies in the future for the maintenance activities by replacing house-keeping activities.

Germany – Conclusions

Shift in the value chain can be observed. Modular construction, which is used in prefabricated house construction, shifts value creation from the construction site to industrial production. The potentials of automation/digitalisation in industrial production lie in enabling cost savings (reduction of waste) and in shortening construction time (Grundke 2019). The potentials of automation/digitalisation in industrial production are far greater than those on the construction site. The resulting comparative advantages could lead to a strengthening of industrial production within the construction industry and reduce the importance of classic “on-site” construction.

MühgeG., Harbecke T., Germany, Case Studies, Report, 2021

3. Impacts on employment: new professions, new skills, training, risk of replacement and polarization

The relations between digitalisation and organizing processes have deep impacts on the employment, considering all the professional figures.

Digitalisation is strictly related to the **increase of high specialized and skilled new profiles** (as BIM specialist, BIM, manager, as well as profiles to manage data and their legal security) **and added knowledge for traditional profiles** (architects, engineers, project managers, technical office, robot maintenance) for design, management and operative tasks; to a **gradual qualification of on-site activities** (for blue and especially for the white collar workers) but also to a **reduction of certain profiles in the construction site** (for example, bricklayer, tiler); to an **increase in the blue-collar for off-site activities**, assembly and maintenance; a general **increase in the white collars for administrative tasks**.

SPAIN - Case studies - Conclusions

in the analysed companies there has not been a remarkable reduction in employment as a result of the incorporation of technologies. Their position in the value chain could explain this. It is likely that employment reduction is externalized and assumed by subcontractors. On the other hand, there is an impact of COVID-19 on the companies, firstly configured on short-time shems and laterly on employment reductions caused by reduction of economic activity.

Cruces Aguilera J., de la Fuente Sanz L., Spain Case Studies, Report, 2021

In many cases, there is the introduction of some new occupations but the general trend is the re-skilling of previous professional profiles, both on on-site and off-site level, even because the adoption of these technologies is spread especially among big companies usually oriented toward continuous innovation processes.

For many workers, tasks have only partly changed to be adapted to the use of new machines and the type of work has not changed. Low qualified and older workers have more difficulty using digital tools and this can create inequalities.

If digital skills will become a basic competency for construction employees in the foreseeable future, it seems that in the work processes a significant level of experience remains crucial and professional skills are still considered more important than digital skills.

Considering new profiles and competences, there is a mix between high specialization and knowledge of the construction process as a whole to guarantee flexibility as well as standardized coordination. Moreover, all the profiles need a greater knowledge in the use of software and ICT, as the common language and framework of the communication system in the value chain. The integrated management of all company departments has required more cross-sectoral skills on the part of workers, who have thus realised they operate in a complex and wide system in which all parts are interconnected.

Digitalisation is more related to a transformation of the traditional professional profiles than to a decrease of the working force. Although robots replace some activities, jobs can be created in other areas of the value chain (as pre-fabrication, maintenance, management) as a result of a general shift (also in the same group). However, looking at the growing digitalisation of the sector and the growing competition, low-skilled workers, especially in small companies, risk a reduction of their occupational opportunities. In many cases, innovation needs to cope at one hand with the expectative and, on the other, with the possible resistances among employees towards a great working change. In some cases, especially for the highly skilled professions, “external workers are hired mainly to fill more specific job vacancies and positions such as those related to the development of design and planning in the furniture sector” (Rugiero, Di Nunzio, De Angelis, Brachini, 2021). In other cases, companies prefer to keep specific skills internally and use the labour market option for low-skilled tasks and work processes that digital technologies, such as robotics production lines, made easier to carry out. In the latter case, it seems that new technologies favour a deskilling of the labour force.

BELGIUM – Case studies- Two sister companies

Digitalisation simplifies the remaining tasks to be carried out by the workers. Skills associated with these tasks are hence easier to find and more available on the labour market. This in turns can justify the use of subcontractors rather than salaried contracts as there is no need to keep the related skills internally.

Franssenn M. , MOBIC/SCIDUS, National Case Study Report, 1, Belgium, Discus Project, 2021

For the future, another potential risk to employment could be the internationalization of the workforce favoured by the possibility of remote work due to the centralization of work through digital platforms and, potentially, the development of a “lowest bidder” competition between workers from different countries (wage dumping).

Definitely, the introduction of digital technologies has registered the main effects in the **qualitative dimension of work rather than the quantitative one**.

New work requirements and the need for adequate qualifications for a new organization of work induced by the processes of digitization create a constant demand for updating and makes lifelong learning crucial. However, many workers still lack basic digital skills. The qualification and training regarding new technologies are provided mainly for managerial staff (the high-skilled employees in the core company of the value chain), with less opportunities for the workers at the building site. These insufficient training and inadequacies in the education system can lead to severe skills shortages are therefore to key issues in the debate on innovation and digitalization of construction work.

The differences in skills, working qualification and training are key factors in the growing **polarization of the working conditions and wages** in relation to the uses of digital technologies (for examples BIM and non-BIM profiles), and to the lack of certain digital and transversal skills both for high-skilled professions (as architects, engineers, draftsmen who are less or more keen on use a platform) and for low-skilled professions (also considering the high average age of workers in the construction sector).

Bulgaria - Case B - European-based technology group for construction services

The staff look at the processes of the suppliers and examine possible intersections. In keeping with corporate value of partnership, the company have therefore begun to offer BIM 5D® training (Building Information Modelling) to its external partner companies so that they can develop the standards of the future together. The company also provide their partner companies with group tools for use, for example to digitally manage logistics chains across several value creation stages. [..]

The qualification and training regarding new technologies are provided mainly for managerial staff, and very rear for workers at the building site – thus there is a lack of new skills needed for new work organisation.

WETCO, Bulgaria, Case Studies, Report, 2021

4. Working conditions

Digitalization the sector leads to a deep modification of many working conditions aspects and this section tries to summarize the main findings of the case studies with a focus on three relevant issues: occupational health and safety, workload and intensification, participation and coordination.

4.1. Occupational health and safety

Most part of the actors agree about the great **opportunities of digitalisation to improve the working conditions**, considering in particular:

- reduction of dangerous activities;
- reduction of repetitive and monotonous task;
- reduction of serious accidents;
- production of data and information for monitoring and prevention;
- standardization of tasks and planning;
- reduction of on-site activities;
- more opportunities to control the actors involved in the value chain;
- general qualification of companies and professions in a traditional sector with a low degree of innovation.

On the other side, there are some negative impacts related to the introduction of technologies, and the case studies emphasize in particular the new psycho-social risks associated to new taylorist models on workshops which forces workers to accelerate the work pace and then to adopt risky behaviours.

Even if there is a general agreement about these positive and negative aspects, the in-depth analysis of the relations between digitalization, work organization and working conditions show not univocal aspects. **Impacts on health and safety are related to some intervening factors**, as:

- workers' qualification, knowledge and continuous training as well as their capacity for adaptation to the changes (with most positive impacts on the high-skilled professions and worst impact on the low-skilled groups especially in the marginal companies of the value chain);
- the degree of workers' cooperation and participation (with the relevance of the dialogue along the value chain among companies and between blue and white collars and with worst working conditions where there is a lack of the workers' participation);

- the degree of communication and sharing of information related to working conditions (time-sheet, presence of the work-force, high risk activities, accidents etc.);
- the preventive OHS organizing model, with the relevance to improve the relations between all the actors of the preventive systems and the organizing system.

In particular, the increased predictability and programming of the work phases and the organization of the work right from the design phase allow favouring an “inside prediction” approach, passing **from a reactive to a predictive attitude** regarding the above mentioned topics.

From a trade union point of view, the advantages that such changes can have in terms of greater opportunities for accident prevention and OSH protection are of particular importance.

The “**immaterial predictive management**” of the construction site, based on inside prediction, creates many material consequences (material vs immaterial dimension). On the one hand, digitalisation might represent a useful decision-making tool, a way to prevent inappropriate behaviour, and mitigate safety risks by preventing critical and unexpected issues; on the other hand, it does raise the issue of the surveillance of workers.

Italy – Company in the wood industry

With specific reference to Health and Safety, it seems that the new organisational management ensures greater safety at the workplace, as all activities are organised in a more organic and systematic manner. The Group is investing ever more capital in health and safety, through training but also through dialogue with union representatives. Bearing this in mind, work tools and devices are being used which improve productivity, but also protect workers. A case in point is the purchase of 100% electric forklifts and trucks, which have replaced the diesel-powered ones whose emissions created an unhealthy situation inside the plants.

Rugiero S., Di Nunzio D., De Angelis G., Brachini N., Italy Case Studies, Report, 2021

4.2. Work load and intensification

The digital innovations presented in the case studies can help to **reduce the heavy physical and cognitive workload** with impacts on blue collars as well as on the administration, in particular reducing repetitive tasks.

In some cases, the saving of time and the simplification and optimization of work processes thanks to the use of tools such as tablets allow blue collars workers greater **autonomy** and the possibility of dedicating themselves to the core tasks of their profession (for examples for the employees of the human resources departments and purchasing and logistics who are traditionally forced to

spend a lot of time on bureaucratic issues), but at the same time these digital technologies strengthen control of workers' activities by the tool.

Belgium – Case 3 - General construction company, family business

For the HR in charge of workers, the new software also allows a clearer vision of the schedules. She actually says that thanks to her overview on them, she more easily detects potential mistakes, which can now be rectified very quickly. Consequently, it ensures better daily monitoring of work on sites and a greater responsiveness to the vagaries of everyday life. Obviously, this requires more communication with team leaders, but it is more fluid. [...]As previously mentioned, within the logistics and purchasing department, information is now centralized. If this facilitates the work of employees, according to the manager, it also strengthens coordination with workers. [...] From the blue-collar workers' point of view, it is possible that this situation is perceived as more controlling.

Pere M., Belgium Case Studies, Report, 2021

In other cases, the digitalisation of work puts pressure on the organization to work together under constraints and this can result in multitasking of the employees, short time and more or less stressful and intensive work. This causes resistance to change and it is one of the main obstacles to the widespread use of the BIM.

In particular, with BIM the **workflow has more load in the initial phases and less on the construction site**. The use of BIM methodology has led to an increase in the workloads of workers and technical departments, especially in the initial implementation. An increase in the working time of technical offices is registered, while execution times and deadlines in the work are reduced.

However, BIM-related tasks on site present high risks in terms of workload and working time **saturation for the supervisor of the site** due to the difficulty on site in keeping up with the continuous design changes further accelerated by digitalisation with respect to the operational time required for the execution (increased separation between the planning and the executive part).

One of the most important aspect is related to **increase in flexibility** and in the opportunities for a **continuous and quick redefinition of the building project**, to satisfy the buyers' requests or to cope with some unforeseen problem, even without an exchange with the on-field actors, with the risk of a centralization of the reviews and with an intensification of the work activities.

ITALY – Case Studies – Engineering Company

On the executive level, on site, “It feels like a race against time in achieving a technological innovation that is very rapid. Previously, design times were as slow as the executive ones might be, they were two manual jobs, done by people, different but human; instead, this very fast innovation makes it difficult to update and execute the works”. [...] “At each change it is necessary to speak with the workers who have to carry out the change, to recontact the suppliers of the materials, with problems with the supply chain. So time is taken away from controlling the activities. Compared to the past, we are much more drawn into the construction site offices to look at drawings because I find changes, and to share them with the site manager. But there are also important consequences for safety”.

Rugiero S., Di Nunzio D., De Angelis G., Brachini N., National Case Studies report, Italy, Discus Project, 2021

FRANCE – Case studies A - Medium group

BIM is very new and it seems very complicated to the works managers. The feeling is that, given the need to constantly modify/update the information in the model, it could mean spending all day in front of the computer and the foremen are already overwhelmed with emails. I therefore feel that BIM-related tasks on site would require dedicated people and therefore hiring

Teissier C., BIM in SMEs – a reality?, National Case Studies report, France, Discus Project, 2021

From the point of view of the autonomy of operators in the execution of work tasks, in BIM projects the changes to be made leave less freedom on the site in solving any problems making use of the construction experience of workers, due the greater standardization of the process.

Under the pressure of the reduction of waste and of a common framework all the actors are oriented to **intensify their performance with a flexible attitude**.

The **gap between the speed of technological development and the manual component** (i.e. the digital and analogue approaches) have also consequences for safety, requiring new intervention of prevention systems on site after each change of the project.

Prefabrication reduces work on site but intensifies planning and manufacturing with specific work overloads in the office. Moreover, the growing role of the pre-fabrication increases repetitive tasks at on-site level, even in presence of automation.

Finally, considering the cognitive aspects related to the introductions of new technologies and work processes, digitalisation increases the **workers' need for new ICT knowledge** as well as continuous training, contributing to the intensification of the working time as well as in the workloads.

For white collars, there are more opportunities for work-life balance due to teleworking, although an intensification of workload could be registered.

SPAIN - Case C - Big company with presence in different activities

From the workers' point of view, there are no great reserves. Although it has been a process with specific moments of work overload, there have been no complaints about the implementation of the system. If anything, complaints have been registered for implantation failures and for not being 100% working with the system. According to the company and the workers, as a result of the digital process, the staffs are more involved in the construction process and with a higher commitment, having a greater understanding of it.

Cruces Aguilera J., de la Fuente Sanz L., Spain Case Studies, Report, 2021

4.3. Covid-19 pandemic

The case studies are analysed during the Covid-19 pandemic and there are some specific aspects strictly related to this phase, in particular considering the safety procedures at on-site and off-site levels as well as the wide introduction of tele-work among the white collars.

From the one hand, it seems that the Covid-19 pandemic can accelerate the digital transformation of companies in making the building site a safer place. In fact, there are many technologies that has emerged in the context of the pandemic: smart devices to reduce the direct contact between employees and the extension of telecommuting and remote work procedures implying a change in business culture and ways of working.

In any case, the impact of Covid-19 in the digitalisation processes seems to favour an increasing attention on safety conditions with a new balance between safety and security.

5. Work relations: participation, cooperation, coordination

Some digital frameworks, as BIM, aim to increase the coordination among actors in the highly fragmented and flexible building value chain. Thus, planning, data, standardization, control, in a common framework, increase the actors' opportunities for coordination and communication, without the space and time restriction as well as the company borders. In particular, there are many opportunities to cope with the high fragmentation of the construction phase, with an improvement of the coordination between different companies working together on a site.

Digital data sharing and interoperability lead to a systemic and collaborative approach instead of the traditional "layered" and overlapping approach (**synchronization and collaboration vs. stratification and hierarchy**).

Also the issue of the **transparency** of digital information between all the actors is a relevant aspect to improve coordination and also to reduce irregularities that are wide problem in the construction sector.

However, this common framework is always under construction as well as **under pressure**, due to many factors, such as the lack of a shared knowledge among all the actors and companies, the lack of a common software and language, or the orientation towards a continuous change.

In this relation system, **intermediate management plays a rising key role** - as intervening actor - between the high management, digital platforms and the workforce on-site and off-site. These intermediate figures facilitate the digital workflow all along the construction process, in order to give professional support and to implement the technical processes.

Some actors underline the risk of reduction in autonomy, for the workers as well as for the companies on the marginal role of the value chain, due to a greater centralization of the working project.

Thus, digitalisation is related at one side to an high specialization and **segmentation** of the working tasks of the projects, with a certain risk of fragmentation, on the other side it try to improve the **coordination**, by common models and the production and sharing of data, information, knowledge, with a certain risk of unilateral centralization.

Considering the **company size**, there are differences in terms of the internal implementation and resources to make the digital change. For example, small companies have less resources and innovation capacity but, also, less internal obstacles when they decide to implement digital change within their structures. In contrast, big companies could have more internal impediments.

6. Industrial relations and social dialogue

6.1. Trade unions' presence, logics of action and broadness of the bargaining topics

The challenge of digital transition touches many dimensions of the role of workers and trade unions and the principles and practices of industrial relations, as we underlined in the previous paragraphs. The role of industrial relations on digitalisation has been analysed considering three relevant analytical dimensions (table 3):

- a) the **presence of trade unions** (presence or absence of workers' representatives in the case study);
- b) the **logic of action of trade unions** (passive, reactive, proactive, considering the opportunity to have voice and to govern the process with a less or more anticipatory and continuous approach);
- c) the **broadness of the bargaining topics** (low, medium or high, considering the impacts of bargaining on digitalisation on few or many aspects of the working process).

Case studies are analysed in a comparative perspective with the aim to underline specificities, common trends and divergences considering these three analytical dimensions.

Table 3. Digitalisation and industrial relations: the role of trade unions

Country	Case study	Workers' Representatives	Logics of industrial relations				Coverage of collective bargaining: main topics related to digitalisation (breadth)		
		Presence	Passive	Reactive	Proactive	Low	Medium	High	
Belgium	Multinational company	Yes	Digitalisation is not really part of the debates				Safety, Working Time		
	Two sister companies	No	Workers' involvement by management			Training			
	Family business company	No	Workers' involvement by management			Training			
Bulgaria	European technology group	Yes			Trade union has long-term cooperation with the company management.		Information and consultation, employees' qualification, training		
	Company specialized in commercial/technical issues	No	Workers' involvement by management			Training			
France	Medium group	Yes	Social dialogue on digital transformation, to anticipating its effects still seems to be emerging				Training, health and safety		
	Small independent company	No	Workers' involvement by management			Training			
Germany	Building materials industry	Yes High fragmentation (sectoral level)		Difficulties in collaborative construction planning, lack of a uniform standard		Resource efficiency			
	Company of the pre-fabricated house	Yes Works council			Digitalisation is a regular topic for co-determination			Specific agreements on digitalisation	
	Germany's largest construction company	Yes IT committee			Co-determination processes			Regulatory process for the introduction of new IT systems	

Italy	Engineering company	Yes Bilateral bodies	Social dialogue on digitalisation is weak or at a very early phase				Legality and irregular work, Training	
	Construction site	Yes Fragmentation Bilateral body		Union should anticipate digitalisation, by participating in the process and not just reacting			Legality and irregular work, health and safety, training	
	Company in the wood industry	Yes			Dialogue between the parties has been continuous			Supplementary agreement provides for information at both territorial and national levels on issues relating to the technological innovations introduced by the Group
Spain	Multinational business group of construction	Yes		Social agents have not negotiated issues related to the impacts of digital change on working conditions			Use of technologies and rights of disconnection of work	
	Medium company	Yes Work council			Works council is called to participate to the implementation of technologies and productivity plans			Training, autonomy and participation, working conditions
	Large business group dedicated to construction	Yes Work council	Industrial relations are at an initial stage in the company			Training, re-qualification and digital skills		

As underlined in most part of the cases, digitalisation can offer new opportunities for the industrial relations systems and social dialogue. On the one hand, **social partners usually consider IT innovation as an opportunity** for the working conditions and there is a low degree of conflicts about the topic itself, on the other, **the level of collective negotiation needs to be enforced at company and sectoral level.**

Trade unions are absent especially in the smallest companies and family businesses. In these cases, workers are involved by the manager with the aim to facilitate the introduction and application of digital processes, especially considering the relevance of their **training** (a key topic in all the case studies).

At the present stage, even in the companies where there are workers' representatives, their role to address digitalisation is still weak in most of the cases (with a **passive or a just reactive role**). In these cases, opportunities for negotiation present some obstacles, with a strong leadership of the management, also with the use of "intermediate professional profiles" with the role to facilitate the introduction and application of digitalisation process at any level of the value chain.

In the case studies where trade unions seem to have a **passive role**, the process of digitalisation has been introduced without a dialogue with the workers' representatives. Digitalisation is not really part of the debates (as in the Belgian case) or negotiation is at a very early stage (as in the French, Spanish, Italian cases), with a growing awareness about the relevance to play a role in these processes. Main bargaining topics are oriented toward the affirmation of some basic workers' rights: training, health and safety, regular work.

These cases show the risk of a polarization of the opportunities of participation, with a highest involvement for the high-skilled workers in the core activities, also in the biggest companies.

Belgium – Case 1 – Multinational companies

Another reason is that the use of BIM is currently limited to managerial and rather technical functions. BIM has currently little impact on actual construction sites. According to the head of infrastructure works, trade union demands mainly focus on working time, breaks, and pay. If BIM is not yet really a subject to be addressed in social dialogue, "it is because it is still very theoretical at this stage" (BIM expert, Colas Projects). At this stage, BIM also has a greater impact on work organization than on working conditions, making it a source of little concern to trade unions compared to issues that are more "traditional", according to our interviewee.

Wuidar S., Belgium Case Studies, Report, 2021

Case studies where trade unions have a reactive role, workers' representatives try to cope with the digitalisation and innovations but with a low degree of participation. In some cases the lack of voice is due to the fragmentation at sectoral level (as in the German building material industry) or at site level (as in the Italian construction site), but problem for the trade union's participation are present also in the big companies (as the Spanish multinational group), considering the opportunities to negotiate not just the introduction but also the impacts of digitalisation on the working conditions. Bargaining topics are in part oriented toward the affirmation of basic workers' rights or focused on the management point of view (the economic aspects or the efficiency). However, the increasing role of the ICT seems to introduce new bargaining topics as the use of technologies and the right of disconnection of work (as in the Spanish multinational). However it seems that there is a low consideration of the strict relation between digitalisation and all the aspects of the work organization. In the cases where the trade unions play a **reactive role**, workers' representatives play a key role at company as well as sectoral and building site to control the regular application of the laws and agreements, with positive impacts to improve the working conditions.

France – Case A - Medium group – General contractor

It is a much larger company with staff representatives, namely a social and economic committee comprising 4 full members and two union delegates, one a member of the CFE CGC, the other of the CGT. In this institutional context, social relations are seen in a very positive way by both management and the staff representative interviewed. [...] Although the social climate is good, social dialogue specifically dedicated to the digital transformation of the company, or, more importantly, to anticipating its effects, still seems to be emerging. The CSE is certainly aware of the training budgets relating to this transformation, as it has to be consulted on this point. On the other hand, the staff representative has no recollection of an information/consultation procedure relating to the introduction of new technologies in the company (Article L.2312-8 of the Labour Code). This does not mean that the introduction of BIM was not discussed in the company, as management stresses the importance of informal relations in the company and the staff representative

Teissier C., France Case Studies, Report, 2021

Negotiation is strongest where there is a strong industrial relation system and a formalized role of the trade unions about the introduction and development of digitalisation, especially in association with the presence **of work councils, bilateral committee, co-determination systems**, as in the German, Italian and Spanish cases.

A **pro-active** role is based on the presence of trade unions and a strong industrial relation system, and it is often associated with the presence of **specific agreements and procedures about the introduction of innovations and digitalisation**, with the aim to favour the workers' participation and the evaluation and monitoring of the impacts on work organization.

Big companies and pre-fabrication industries are more oriented towards the adoption of bargaining procedures, with **pro-active approaches**.

Germany - Germany's multinational company

Germany's largest construction group, it is no longer possible to imagine the Group without employee co-determination. Management and employee representatives work together in a spirit of trust. There is also a functioning social partnership with the IG BAU trade union, which has a strong position within the company and negotiates the company's collective agreements. Co-determination processes are common practice in the Group and, in addition to the works councils in the individual plants, there is also a Group works council that deals with all digitalisation matters. For this purpose, the Group works council has set up a six-member committee to deal with all IT topics. Group works agreements have already been negotiated in the IT committee.

MühgeG., Harbecke T., Germany, Case Studies, Report, 2021

In companies where a strongest industrial relation system is present with a trade unions' proactive role (as in the case of the work council in Spain, Germany and Italy), digitalisation adds continuously new topics to the bargaining process. Negotiations try to consider several aspects, such as the rights of training and health and safety, but also the rights of the workers' information and participation as well as the working conditions and work organization in terms of workload and autonomy.

At general level, some other relevant bargaining topics often related to digitalisation are: restructuring process and work substitution; the use of data with the aim to avoid the risk of workers' surveillance; tele-work, also considering the right to disconnect, even in consequence of the Covid-19 pandemic.

A more proactive logic is often associated with a broad bargaining perspective, with the opportunities to consider several topics in association to digitalisation.

6.2. Orientations of trade union action

Even where there is a proactive trade union role, **bargaining is expressed especially at company level**, with few or no impacts on the other companies of the value chain, even when there is a public buyer.

Most of the actors agree about the relevance of improving the social dialogue on digitalisation at sectoral level, because this topic is not considered adequately, with the aim to **provide guidelines, standards and general rules for the negotiation** at territorial and company level.

In particular, it seems relevant to **favourite the relation between industrial, construction and public sector** about the most relevant topics of digitalisation, as the relations **between in-site and off-site activities, pre-fabrication, production and sharing of data and information, training, control on the value chain and on the regular workforce**.

Constant presence and active role for the union in deciding on the introduction of digital innovations (changes in the management systems, restructuring process, training, sharing of data) are needed to use digitalization as a tool to improve workers' safety and productivity conditions, and to avoid the risk of the use the digitalization just for surveillance systems.

This suggests the need for interventions that are **not simply reactive** in terms of justice or job protection, **but proactively** intervene to shape the nature of the digital transition leading to a fair technological transition.

For these reasons, it is important that the social partners innovate their negotiation practices: with new matters taking **anticipating stances and involving trade unions proactively** (no longer just with reactive participation) in negotiating such changes.

In particular, as emerged in the most proactive cases, the **planning phase** becomes a key moment to define the work organization and working conditions along all the value chain, with deep impact also on on-site activities.

Italy – BIM case studies

In the case studies, the relation between BIM, bargaining and social dialogue is weak or at a very early phase. Generally, the previous situation of the industrial relations system influences the relationship between managers and workers, but without a specific impact on the application of BIM.

However, there are some relevant aspects we can consider to strengthen the role of the social partners and institutions in the BIM process. The challenge of digital transition touches on many dimensions of the role of workers and trade unions in society and the principles and practices of industrial relations.

The greater importance of the project and planning phase can help to strengthen the “advance bargaining system”, increasing the participation of trade unions, workers' representatives and workers in the design phase of the project, giving them the opportunity to have a voice in the whole working process.

However, there are also some risks associated with the specific features of BIM, such as a centralisation of project management and a separation between the design phase and the material building process and, so, between white- and blue-collar workers. Also, there is a risk of a segmentation in the industrial relations system between sectors, in particular between on-site and off-site companies, with an impact at site level. To avoid this, it is helpful to improve the agreement for the OHS representatives at site level.

Rugiero S., Di Nunzio D., De Angelis G., Brachini N., Italy Case Studies, Report, 2021

In synthesis, it emerges that in most part of the case studies the negotiation about digitalisation is still incipient. Even where there is a reactive or proactive role, as in Germany, it needs to strengthen trade union action, also considering employee representatives in the company to make them aware of the issues associated with the digitalization, such as data security, training for employees, etc. Finally, it is useful to consider the impacts of the high segmentation of the construction value chain on the trade union action. The main trend for the company is to develop sub-contracting chains rather than using salaried contracts. This recruitment choice has an important consequence in terms of social dialogue starting from the consideration that subcontracting makes it possible to keep the number of salaried workers below the legal limits for setting up social dialogue systems. In addition, these subcontracting companies will often belong to different joint committees than the construction one, potentially less favourable (ex : lowest minimum wage) and no longer taking into account the specific working conditions of that industry (ex. bad weather compensation).

The relevance of social dialogue along the value chain is also due to the close relationship between digitalisation processes and the increased possibilities for segmentation of the production process and sub-contracting.

Belgium – Case study n.1 - Sister companies in the wood construction sector

Regarding industrial relations, this case study illustrate how digitalisation can be a threat to formal social dialogue structures. New technologies seem to favour a deskilling of the labour force, making it more available on the labour market. The use of sub-contracting chains is thus facilitated. As subcontractors are not accounted for in the employment volume from which is it possible to establish a trade union delegation, this representation mechanism will be delayed in the enterprises that relies on subcontractors. The consequence is an apparent weak dynamic of social dialogue on the topic of digitalisation, even though these organisational transformations have a strong impact on working conditions. In this sense, digitalisation calls into question the relevance of the current regulatory framework on this matter.

Franssen M., Belgium Case Studies, Report, 2021

6.3. Digitalization and environment: for a broad social dialogue

Sustainability and digitalisation are the two main drivers for the development of the construction sector, and inevitably they interconnect, at company, territorial and sectoral level.

Digital transition need a 'broader scope notion' of what is meant by innovation addressing not only a radical technological change but a **societal transformative change**: novelty in services, organiza-

tions and business models and urban development, as well as in the principles and practices of industrial relations and in the role that trade union action can and must have in governing these processes.

As emerged by some emblematic case studies of companies oriented towards **sustainability and circular economy**, digitalisation can accelerate technological innovation processes related to protection of the environment. In fact, all innovations have a decisive impact on the environment and energy, with new risks and new opportunities for the sustainability and the most part of actors seems to emphasize the potential benefits.

SPAIN – Case study A - Big company with presence in different activities

These innovations are closely linked to the circular economy, in the use of waste from other industries (such as, levelling of soils and associated activities). According to the interviewers, their incorporation has meant an advance with respect to the information that the company has about the construction process. With them, many parameters of the building process can be measured, managing and optimizing resources, both in terms of costs and ecological outputs.

Cruces Aguilera J., de la Fuente Sanz L., Spain Case Studies, Report, 2021

In example, BIM methodology improves construction in terms of energy performance and reduction of wastes both during construction and during use of the buildings. BIM methodology can also provide data for the study of the carbon footprint and other aspects that can be useful for a wider process of regeneration and urban redevelopment as well as the growing relevance of smart cities, smart buildings and green building.

SPAIN – Case study C. Big company with presence in different activities

Standardizing and sequencing of tasks in on-site works allows the reduction of unnecessary trips as well as the reduction of discards of raw materials. Thus, reducing waste in on-site works is a result. Therefore, the company is reducing its ecological footprint. In offices, digitization and paper-less activities also allow an environmental improvement. In maintenance services, the use of IOT in maintenance-sensitive machinery could bring improvements in the carbon footprint by reducing the number of technical services trips.

Cruces Aguilera J., de la Fuente Sanz L., Spain Case Studies, Report, 2021

Digital innovations can be closely linked to the circular economy, in the case of use of waste from other industries eliminating the need for virgin raw materials, for example in the cases of processing and transformation of recycled wood.

ITALY – Case Studies – Company in wood industry

The excellence of Italian wood-furniture is not limited to the high-quality end products, but includes the entire virtuous system of circular economy that hinges around the supply chain. In fact, the Italian wood-furniture sector ranks first in Europe in terms of recycling economy (over 90% of chipboard panels produced in Italy are made of recycled wood) and last in terms of polluting.

Rugiero S., Di Nunzio D., De Angelis G., Brachini N., National Case Studies report, Italy, Discus Project, 2021

Conclusions

The comparative analysis of the case studies shows that digital innovation in the construction is a consequence of multiple technologies (as BIM, robot and automation, software systems) with some general macro-trends and not univocal impacts.

In particular, our findings show some relevant challenges for the social dialogue introduced by the digitalization:

- a strict relation between social and technical aspects.
- the affirmation of lean production and network economy along the construction value chains;
- multiple consequences on professions, work organization and working conditions;
- the need for the trade unions and social partner to adopt a proactive role.

a) The strict relation between social and technical aspects

Digitalization is a sociotechnical transition with economic, social, technological, environmental, cultural change in a multilevel perspective (Bijker et al., 1987; Smith e Stirling, 2010; Geels, 2002). In the construction sector, digitalization connects the evolution of technical tools to the transformation of the social life at company, local, national and global level. This socio-technical change has many impacts on the labour market, professional paths, work organization, working conditions as well as on the public policies and urban development models, in particular considering the affirmation of a sustainability and circular economy (Rugiero et al., 2017; Clarke 2020).

First consideration is that industrial relations and social dialogue needs to address and govern these wide socio-technical changes, with the involvement of public and private actors at any level.

b) Lean production and network economy along the construction value chains

Focusing on the changes in the working conditions and work organization in the construction sector, digitalization favours the affirmation of lean construction models, accelerating a process that began in the 1980s (Howell, 1999) based on a mix between standardization and flexibility (Björnfot & Stehn, 2004; Girmscheid, 2005; Liu et al., 2016; Sacks, 2016). In particular, as emerged by the case studies, these digital innovation aim to standardize the activities in flexible processes and to improve the communication and control among all the phases of the value chain.

Lean construction is strictly linked to the transition from an economy segmented into phases to a network economy in which the various players are connected along the value chain (Kalleberg, 2001; Castells, 1996; Di Nunzio, Rugiero, 2019; Eurofound, 2018; Rifkin, 2014; Huws, 2014; Brynjolfsson, McAfee, 2015; Schwab, 2016) and digitalization is adopted to strengthen the relations and communications between the actors.

Second consideration is that industrial relations needs to cope with complex workplaces and fragmented working processes, with many companies, many professions, off-site and on-site phases, along the value chains.

c) Multiple consequences on professions, work organization and working conditions

As emerged from many studies in different sectors, digitalization have multiple and not univocal impacts on the labour market and the quality of working life (Degryse 2016; Valenduc & Vendramin 2016; Eurofound 2018).

Our case studies shows that also in construction industry there are differentiated impacts on the labour market, with the emergence of new professions and the need for re-skilling and continuous training for many others, for the white and blue collars.

Digitalization can involve each phase of the vale chain, with new professional specializations and new relations between professions. Digitalization can favourite horizontal coordination as well as, on the contrary, vertical centralization. In particular, the planning phase assume a key role for all the phases of the value chain to favour a more or less participative process and a dialogue between the management, team leaders and workers at off-site and on-site level.

Regarding the working conditions, there is a trend towards a general work intensification for white and blue collars. On one hand there are new risks, as the increase in the pace of work, work related stress, new risk associated to new machinery materials, procedures. On the other, there are new opportunities, especially considering the collective use of data and information for OHS prevention;

reduction of workload due to the use of robot and automation; opportunity to program the workload and to monitor irregular work and accidents.

Third consideration is that these processes are the result of the use of the technology and all the actors (employers' associations, workers and trade unions, institutions, etc.) play a basic role to plan the adoption of the digitalization and to govern its impacts.

d) Strengthening the role of trade unions and social partners: for a proactive role

Thus, the role of intervening actors is basic to govern and to address the impacts of digitalization. Focusing on the role of the trade unions, we observed, in most part of the cases, the risk of the marginalization of workers' representatives (in favour a merely technical approach led by the management) with a passive role of the workers' representatives. On the other hand, there are some trade unions' attempt to assume a reactive role, or, in few cases, a proactive one. A proactive role is based on the search for agreements and formalization of the role of trade unions and workers' participation, and it is based on approaches oriented towards the anticipation of changes and on the participation of workers' and their representatives starting from the planning phases.

However, in most part of the cases, our case studies show a fragmented dialogue, a lack of involvement of the trade unions and limits for the workers' participation.

For this reason, the final consideration is about the relevance to strengthen the formalization of the social dialogue and industrial relations to support the digitalization of the construction sector. Public regulations have a key role to affirm the role of the social partners, in a sector where trade unions have a passive role and where legal and public regulations of the construction activity is a determining factor. Employers' association and trade unions needs to define shared procedures at national and company level to support the participation of workers and their representatives, with a focus on the planning phase and on the relation between different companies of the value chains at off-site and in-site level.

In particular, considering the continuous evolution of digital innovations, it is relevant to support the analysis and exchange of the practices and training of institutions, employers' associations and workers' representatives based not only on technical skills but also on the awareness of the social aspects.

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