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Digital transformation in the construction sector: challenges and opportunities

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CASE STUDY N°1
MOBIC/SCIDUS

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Introduction

Digitalisation and technological changes have specific impacts on the construction sector. They involve new challenges on both organisational and industrial relations' aspects. In order to document these impacts and challenges from a qualitative perspective, we present in this document the results of a case study led in the sister companies Mobic and Scidus. Strongly anchored in the field, it addresses the impacts of the introduction of robotic production lines on the organisational and social dialogue aspects of these construction companies.

Two aspects motivated the selection of these companies. First, Mobic and Scidus dedicate most of their activities to prefabrication in one of the main branches of the construction sector. Indeed, they operate in the wood construction sector, more specifically in the timber frame constructions market. Second, the companies' developments towards digitalisation are considered to be among the most advanced in their sector in Belgium.

Mobic's activities are oriented towards design and sales of the structures; while Scidus takes on the production part (log cutting, panel assembly and house finishing). Both companies are part of a larger Group, whose parent company is IMAX Pro. IMAX Pro activities are dedicated to the research, development and commercialisation of the robotic production lines at large scale. This case study primarily focuses on the impact of the robotic production lines on the reality of work of the Group's production site (Scidus), located in Etalle. It secondly addresses the impacts and the relations with the design office (Mobic), located in another village called Harzé. Because of time and resources constraints, the situation of the IMAX Pro company is not addressed in this case study.

The case study is divided in five chapters, as follows. First, we detail the methodology adopted for data collection and analysis. Second, the main characteristics of the case study are presented in terms of company background as well as the main digitalisation and innovations adopted. Third, we address the impacts of those technologies on three organisational dimensions (work organisation, labour force, working conditions). Fourth, the relation between the technologies and industrial relations is exposed. Fifth and finally, the main drivers and barriers considering digitalisation are listed.

1. Methodology

In order to ensure the validity of the results presented below, we triangulated our data through multiple sources. Preliminary contents were collected during the approval process of the case study given by the company. At the beginning of July 2020, in strict compliance with the sanitary rules, we arranged a 2h30 guided visit of the production halls in Etalle by the Scidus' director. This visit allowed us to grasp the situation in the field and to get an overview of the entire production process. Six semi-structured interviews which form the core element of our approach, were carried out over the period of mid-July – mid-December 2020. Given the COVID-19 pandemic situation at that time and a change in health regulations, they were conducted by phone calls or videoconferences

and lasted between 20 and 60 minutes. The table below summarises the interviewees' role. Throughout the writing period, desk research allowed us to confirm or clarify elements given by the interviewees. It mainly consists of the website of the companies, newspaper and online media clippings, as well as videos, and websites of connected organisations such as Digital Wallonia. Following the writing of the main corpus of the document, a last phone call was organised at the beginning of 2021 with the Scidus' director in order to clarify specific points of which we wanted to deepen our understanding.

Interviewee 1	Mobic's founder and director[1]
Interviewee 2	Design office manager
Interviewee 3	Scidus' director
Interviewee 4	Assistant production manager
Interviewee 5	Joiner
Interviewee 6	Former worker

Table 1 - Interviews summary

2. Main characteristics of the case study

2.1. The companies

The technological innovations currently implemented within the production halls originate in 1988 with the creation of IMAX Pro. IMAX Pro initially specialises in automation and fibre optic deployment, far from the wood sector. It operates in those fields for about ten years, capitalising on a strong technical background from the founders (two brothers, both holding engineering degrees). In 1998, when creating Mobic (see next paragraph), they orientate IMAX Pro's activities towards robotic. IMAX Pro researches focus on lowering production costs of the timber frame market by industrialising the production with machines. In 2008, the company succeeds in developing the first robotic production line (V1) for wood framing, based on robots from the automotive industry. Since then, IMAX Pro continues its research activities towards new and more complex robotic solutions, including a V2 of their robotic production line.

As stated above, IMAX Pro founders' create Mobic in 1998. From the start, they dedicate its activities to the construction of timber frame houses. The production hall is located right next to the design office, in Harzé. At the time, production work is manual. Workers (carpenters and joiners) carry out wall manufacturing and panelling. Engineers in the design office already work with 3D files, from which machines files are exported for logs cutting. In 2008, manufacturing and panelling are automated through the implementation of the V1 developed by IMAX Pro. As Mobic expands, the original production hall of Harzé becomes too small to support production capacity and new facilities are built on the same site. In 2015, management decides to take over the Scidus sawmill and its production halls in Etalle (100km away from Harzé). Control over a larger part of

[1] Mobic was founded by two persons but we only interviewed one of them.

the value chain expands. In March 2020, all the Mobic's workshops from Harzé are repatriated to the sawmill site in Etalle, along with a switch to a just-in-time (JIT) production system. As a result of the lasts years' researches of the IMAX Pro team, a new innovative and flexible robotic line (V2) is developed to maximise the industrial potential of timber frame construction in new markets. It is implemented in June 2020 and was expected to be fully operational in January 2021.

All of the woods mounted in production comes from short supply chain (50km^2 around production site). Based on the machine files sent by the design office and optimised by the assistant production manager, they are cut in Scidus' sawmill to the needed sizes. The sawmill also provides connected wooden products such as terraces, siding and parquet flooring. Mobic's premises in Harzé are now entirely dedicated to the design office, site supervision and sales activities.

Mobic has patented eight different technologies related to different parts of the wooden frame construction process (roofing, walls, frameworks, floors). These technologies aim at improving the thermal, acoustic and mechanical qualities of their buildings. Both Mobic and Scidus received several labels related to wood supplies (such as the "Local Wood" label which guarantees that raw material are supplied within a 150 km radius around the sawmill) and energy consumption, and certifications related to sustainable forest management (such as the "Programme for the Endorsement of Forest Certification").

Companies are organised by departments and functions. A few persons assure several functions at the same time. Overall, each of the three company employs between 15 and 20 salaried persons. Scidus also has recourse to a substantial number of subcontractors, which can double or triple its number of workers at a given time. Overall, the ownership structure remains largely a family property, and the turnover tripled over the last year.

Mobic is directed by one of the two founding brothers. One person, who supervises seven drafters, manages the design office department. Sales department is made up of five persons: on the one side, the two founders and the Scidus' director, who are general salespersons; one the other side, two sales representatives specialised in houses selling. The R&D department consists of two people who report directly to the director. Three persons work in the administrative department (one in Harzé, two in Etalle), which services are mutualised for the three companies. Scidus is directed by one person. A manager oversees the entire production department (sawmill, paintings, dry kiln, wood calibration and grooving), accompanied by an assistant manager who has specific responsibility for the three workshops described in the next section. A foreman, who reports to the production manager, coordinates the work of the operators (between 40 and 60 operators, depending on orders' volume). The foreman as well as substantial part of these operators are subcontractors. In the sawmill, six workers are posted along the motorised sawing line to supervise and operate the cut of logs into lumbers. Scidus also includes a maintenance and development department, made up of one manager and four workers (two of them being subcontractors); as well as a sales and purchasing department made up of a single worker. IMAX Pro is directed by one person. The director supervises the work of two departments. On the one hand, the robot & web department in which six developers, engineers and designers work on the development of robotic

solutions. On the other hand, the electro-mechanics department comprises an industrial designer, a workshop manager and a team of three workers in charge of the electrical installations.

2.2. Digitalisation and innovations

Main digitalisation and innovations adopted by the companies

As of today, the production halls (now located in Etalle) revolve around three types of workshops.

- The first workshop is a 2D workshop equipped with three workstations. One "Speed-Cut" that machines and cuts wood sections coming from the sawmill, one assembly table and the first robotic line (V1) consisting of three robots. The workshop delivers isolated and closed 2D walls sections. Part of the production is shipped as such directly to on-site constructions. In that case, the client's contractors perform assembly as well as finishing on-site. The rest of the production is sent to the second workshop.
- The second workshop is a 3D workshop operating as an off-site construction site inside the production halls. It is divided into two segments. One segment deals with single-family dwelling units, the other with series productions of houses for holiday resorts. The outcomes of this workshop consist of finished and equipped 3D sections of houses. A protective cover is placed around the sections, which are shipped by trucks to the customer's construction site to be assembled as whole. All 3D houses' sections are made of the wall sections produced in the 2D workshop.
- The third workshop is equipped with the second robotic line abovementioned (V2). It deals with the direct cutting of logs for industrial production of complex wood sections and structures.

Two different versions of robotic lines equip the workshops of the production hall for assembling timber frames constructions. They constitute the main technological innovations adopted by the companies. The first one (V1) operates at the end of the first workshop. This robotic line consists of three robots anchored to the ground that pick, cut, place and nail the wooden elements to produce large 2D flat elements (average 10 x 2,5m). As no robotic model fitted the needs of the founders, they based the design model on robots from the automotive industry.

> *There were quite a few machines for the industrial production of frames, but none of them corresponded to what we were looking for. So my brother thought we should start from a robot used in the car industry.* (interview excerpt, Mobic's founder)

IMAX Pro engineers and developers worked on the development of programming softwares that could fit the wood construction sector and the specificities of Mobic's architectural projects. This first static robotic line was launched in 2008 within the company and is operating since then. It essentially deals with automated repetitive tasks and gestures for the manufacturing of 2D wooden framed walls.

Based on the experience accumulated with the V1 and with the evolution of robotics, a second version (V2) of robots has been developed. Instead of being anchored to the ground as the V1 is, this version is characterised by its mobility around a workstation. The V2 also offers greater versatility in the type of work it can handle. Thanks to a system of scanners and tags, the robot is capable of recognising the log to be processed, referencing it and drawing conclusions about what type of operation it can perform on it. Therefore, precise imaging of the log can be obtained before cutting starts. Such elements, combined with a movement system, allow the V2 to position itself correctly in relation to the type of work expected on the trunk or piece of wood placed on a trestle. In this work configuration, the robot placed itself in a very precise position in relation to the log to be cut, rather than the other way around. A tool changer on the robot head ensures versatility. The robot is also collaborative in its work with the operators. It evolves around workers by self-correcting, *i.e.* by rectifying its position in relation to the environment in which it operates. In a nutshell, this second version is dynamic, polyvalent, flexible, and collaborative.

In the design office, Mobic's architects and engineers have worked since the creation of the enterprise in 1998 with digitalised 3D plans on computers for every new construction projects, contrary to the classical and almost always used 2D paper plans. Asides from allowing the customers an immediate visualisation of the volumes of the projects ordered, the modelled plans are directly sent for production as order forms to the machines and the operators on the robotic lines.

Relations with internal and external stakeholders

The in-house R&D plays an important role in the digitalisation and innovations implemented and, more generally, in the development of the companies. Each of the three companies (IMAX Pro, Mobic, Scidus) has its own team dedicated to research or maintenance and development focusing on their lines of business. IMAX pro develops robotic solutions for the wood industry, which are used in the production halls. Mobic's R&D team focuses on improving the wooden frames by developing patented innovation technologies. The Mobic's team also develops new constructive systems for large buildings in collaboration with the Scidus maintenance and development team on the sawmill and production site. As an example, the large building used for drying the woods after they have been cut has been designed internally and the development team onsite is familiar with

all its operating circuits. Another illustration regards the software running in the robots that the IMAX Pro teams developed internally.

Collaboration and partnerships with universities and the public sector are sought, for a couple of reasons. First, to contribute to the resolution of the numerous technological and research gaps related to industrialisation of the timber frame sector. Second, to consolidate their market position and keep on being at the forefront of technology. Mobic is an ambassador of Digital Wallonia, a regional action plan setting up objectives to reach a digital transformation in several social and economic key themes, including the working world. A PhD financed by the Walloon public research service has been launched in 2019. The PhD student (working half time in the company and half time at the university) has been hired to develop ways of designing and building structures assembled from tree trunks with robotics.

The companies' developments towards digitalisation are considered to be among the most advanced in their sector in Belgium. They are currently the only enterprise in Belgium that manufactures prefabricated wooden structures with robots. Two explaining factors of this situation emerged from our interviews. First, the strong technical academic background of the founders. Second, the differentiated market positioning adopted by the Mobic ever since its creation.

> *From the beginning, we positioned ourselves as managers of an industrial company and not as craftsmen. We knew that we would not be carpenters creating timber frames, but industrialists producing timber frames with cost-reduction as an objective.* (interview excerpt, Mobic's founder and director)

As regards the relations with the BIM in particular, the Scidus' director considers the digitalisation processes implemented throughout Mobic and Scidus as "*a construction type of BIM*", which not only smooths communication between stakeholders but also guides the entire production process.

> *There is a lot of hype going around the BIM. Sure, it helps building cheaper buildings, but it does not necessarily make the construction process quicker and of better quality. In our company, since we cut the woods based on 3D machine files, we already know the dimensions we need as soon as logs enter the sawmill. So we smooth communication between actors, we limit material losses and we optimise design and construction processes.* (interview excerpt, Scidus' director)

This differentiation strategy and the digitalisation associated result in the selling of wood frame products that are partly competitive and partly complementary with the existing offer on the market. On the one hand, single-family dwellings or curtain walls compete with the products offered by other manufacturers in the same sector, and are positioned as both cheaper and of better quality. One the other hand, Mobic is the only company that is able to offer complex wood structures produced at industrial scale while meeting profitable production, thanks to the V2 of the robotic lines. These products relates, *inter alia*, to walls and roofs with unique curves and large formats, complex structures such as the very recent construction of 10 ha of carports made of tree trunks.

3. Impacts of the technologies on organisational aspects

3.1. Impacts on work organisation

Coordination between companies along the value chain

According to the director of Scidus, the wood sector is characterised by a closed and poorly integrated value chain. Actors across the value chain are fragmented and they rarely speak to each other. The use of robotic production lines, materialising the founders' desire of industrialising the sector's production, has enabled the company to grow and extend steadily. This has, in turn, enabled the pursuit of a vertical integration strategy, notably through the acquisition of a sawmill. Vertical integration also takes place at the other end of the value chain. As stated by the director, the aim is to proceed "*on the same tree, from the log to the house*" while minimising financial losses related to the various stages of trunk transformation.

Regarding coordination between companies belonging to the value chain, Mobic wishes to dedicate most of its production to the outcomes of the second and third workshops, *i.e.* to the production of finished and equipped 3D houses blocks (for single-family dwellings or holiday homes) and complex structures (in terms of cutting). The company wishes to avoid the coordination required with construction trades on site when sending 2D panels directly to the construction site. This latest option is thus more and more called to act only as a buffer between two 3D production orders.

> *All this management of sub-contractors on site involves a lot of uncertainty. There are many things that we cannot control. It is a nightmare in terms of management when you send a subcontractor to a building site.* (interview excerpt, design office manager)

Logistics and transportation

The vertical integration strategy and the shift to just-in-time production (see "work processes and tasks" section) supported by technological innovations also led to concomitant changes in transportation system. In 2020, the company repatriated all parts of the production chain currently held on the same geographical site in Etalle. In terms of logistics and transportation, the objectives were to eliminate the management of goods transport between the two previously geographically fragmented production sites, to avoid material leakage, and to create links between the different productions.

On-site and off-site productions

The company wishes to concentrate its activities on the off-site productions of wooden structures, which are the outcomes of their second and third workshops. The second workshop relates to the production of finished and equipped 3D houses blocks, the third to wooden elements of complex structures. In the long term, the direct sending of the 2D panels and closed walls from the first workshop to on-site construction sites will be used exclusively to smooth production between two 3D orders within production halls (off-site production related to the second workshop).

> *Some clients ask us to do closed structural work, and to be able to do the finishing inside the building. But this is not our job. We want to concentrate on prefabrications, on everything that can be done in the workshops* (interview excerpt, design office manager)

As of today, the extent to which the construction project is built on-site or off-site depends on its type. The off-site production is well used for holiday homes, which architectural plans can be mass-produced as they present very little variation from one house to another. For single-family dwellings, the switch is currently being made from closed structural work (2D panels from the first workshop) sent on-site, to off-site production (second workshop). However, the operation requires an individualised approach from the design office for each dwelling, as each customer may expressed different architectural wishes and needs.

Work processes and tasks

The anticipation of assembly processes during the design of the architectural plans by the design office is not new. Indeed, since its creation, Mobic has been working with machine files at the first workshop to produce 2D panels. A prior planning of the positioning of several construction elements is therefore necessary. However, the implementation of the V1 (and later the V2) as well as the increasingly frequent use of these panels for the off-site assembly of house blocks at the second workshop have required extensive planning by the design office and a more complete transformation of information to the production stations. A thorough reflection is required in order to establish in advance the layout of all the elements (*e.g.* cables, doors, electrical sockets, parquet, furniture, water pipes, etc.) that are going to be assembled off-site, so that the robots can panel the wooden elements accordingly. This way of proceeding has an impact on the timing of the work processes. It increases the design time, in favour of a reduction of the production time needed. Nevertheless, in overall, the time between conception and selling in prefabrication is reduced to several days, compared to on-site building, which can take up several weeks.

Vertical differentiation is increased as work is strongly divided between conception and execution. It also affects negatively the flexibility of these working processes and the related tasks, both in the design office and in production.

> *Once the blocks that make up the house are assembled, things cannot be changed anymore. Everything has to be modelled. Each cable has its own path.* (interview excerpt, design office manager)
>
> *When assembling the house at the workshop, I have to anticipate by knowing which parts of the wall we will dismantle for taking apart the modules that we will reassemble on site.* [...] *If a furniture I build falls on a junction of two modules, I have to think about how I'm going to place it so that it can be dismantled. Before, on the building site, I did not think about all that.* (interview excerpt, joiner)

The tasks undertaken by robotic lines can be characterised in several ways, depending the production line on which the task is undertaken.

- Regarding the V1, the use of robots allows maximum standardisation of repetitive tasks such as nailing or panels assembly. Machines orders are established by the design office. They are sent to the production for optimisation (see next paragraph) and then executed by the machines.
- Regarding the V2, the standardisation of cutting is also sought, but applies to complex, technically demanding tasks. The use of lasers with referenced points in a 3D space aims to avoid cutting errors occurring during manual work by a carpenter. Changes between old and new tasks will be characterised through the impact on professions in part 3.2.

Finally, recent changes in the entire production process system have been established. During 2020, along with the repatriation of the entire production onto the Etalle site, the company decided to switch to a just-in-time production system. Its aim is to manage production flows based on demand and not on supply. Previously, a stock of standard size wood sections was produced at Scidus and stored partly at Etalle, partly at Scidus. The design office drew its plans based on these standard size sections and wood was cut accordingly, sometimes requesting a large number of offcuts. As of today, the computer files sent by the design office to the production specify the required wood sizes and cuttings. These orders are optimised by the assistant production manager who then informs the sawmill with the corresponding timber production requests (up to the exact number of wood sections requested). The production orders for the speedcut, the assembly table and the V1 are also optimised so that the machining of the wood reduces the number of offcuts. Regarding the orders for the V2, all three companies of the group are involved. In addition to the drawings and machining files provided by the design office, IMAX Pro sends a robot control file (specific to each cutting order). The JIT is supported by the computerisation and digitalisation of processes, which facilitate coordination between the different departments in terms of information transmission, but also in terms of product traceability.

> *Each wood section we place has a digital twin in the machine file.* [...] *I can inform the sawmill with the exact number of woods that will be needed for each project. Each wood is numbered in the digital machine file, and we also know where each number will fit in the assembly.* (interview excerpt, assistant production manager)

Coordination between services and between workers

Coordination between the design office and the production halls division is ensured by various means. A phone call is scheduled each week between the design office manager and the assistant production manager so that planning at the design office is adjusted to the actual state of production. Each single-family dwelling project starts with a videoconference between the managers and the drafter in charge in order to have an overview of the project. Calls between production and drafters also happen anytime technical problems emerge such as export of the machines files. During project, should the drafters and architects need expert knowledge on particular techniques (such as heating or electricity), internal meetings can be organised between drafters and workers specialised in those techniques from the production hall. However, most drafters and architects have acquired,

throughout the years, a large part of the skills necessary for drawing plans taking into account those techniques (see “training” section in part 3.3).

Work schedule and coordination within workers in the production hall is largely organised by the optimised production orders sent each day to the robotic lines. Workers refer to the files on the machines in order to operate. At the first workshop (V1), orders specify which and how many woods have to be cut, how to assist the robot with assembly and how to finish the panelling of the walls. At the second workshop (3D), orders are used to build and equip houses' blocks with the appropriate construction techniques. At the third workshop (V2), the operator hired (see “profession” section in part 3.3) refers to orders to place and manipulate the logs for appropriate cutting by the machine.

> *Workers implementing files just need to execute the orders. We provide them with the plans in 3D, they have a look and then can conclude "I have to put a pipe of such a diameter here"*». (interview excerpt, design office manager)

This standardisation of processes sought via computerised production orders is intertwined with direct supervision from the assistant production manager as well as from the foreman. At the beginning of the day, the assistant production manager announces the objectives to be achieved according to the orders received by the design office and optimised. For the 2D and 3D parts, the foreman then allocates workers on the basis of work poles (structural assembly, glassware, carpentry, electricity, etc.). Each work pole then rotates through the various construction projects in progress. The assistant production manager checks on the workshops a couple times a day (right after workers allocation and a couple hours later) to supervise each work group and to solve potential problems. The nature of such problems generally varies from workshop to workshop. At the first workshop, the main problems relate to difficulties in reading the construction plans or to breakdowns of the speedcut. Workers are then invited to refer to the 3D model available to get an overall vision of the project. Breakdowns are reported to the maintenance and development department. At the second workshop, requests generally concern the purchase of materials (glue, screws, etc.) which are passed on to the purchasing department. We cannot provide information on that matter for the third workshop since it was not yet operating at full scale at the time of our interviews.

3.2. Impacts on the labour force

Professions

Firstly, we analyse the impact of technological innovations with regard to the workers that are directly concerned by robotic lines in the enterprise. We can qualify the nature of the human-machine interaction as a substitution one, for both lines. However, this substitution applies to tasks of a very different nature depending on the robotic line. For the V1, the substitution takes place on manual tasks that are difficult and repetitive, of which workers are therefore relieved. It applies on products that have been the core of the company's production since the beginning. Consequently,

factory workers have seen an evolution of their function towards that of machine operator, which includes new tasks (see "coordination" section in part 3.1).

> *When they* [factory workers] *were offered the opportunity to move to robotic production lines as operators, some stayed on the* [assembly] *tables but many preferred to move on as machine operators.* [...] *And I'm not sure I would find people who would agree to nail the same nails on the same prefabricated boxes all year round.* (interview excerpt, Mobic's founder)

For the V2, substitution also takes place on manual tasks. These tasks however require a high level of technical expertise, with high cognitive load and offer high added value. Beyond substitution, Mobic is initiating an industrialisation of these technical acts traditionally handled by carpenters, in line with the differentiated market positioning adopted by the founders.

> *The robot for logs* [V2] *enables us to proceed to highly complex technical cuts, to which the only competing profession would be that of a carpenter. But imagine how long it would take a carpenter to produce the volumes we can supply with the machine?* (interview excerpt, Scidus' director)

As the enterprise has invested in this sector of activity through the implementation of the V2 of the robotic line, this function is new within the enterprise. One machine operator was hired for this position.

Secondly, we analyse the impact of technological innovations with regard to the professions indirectly concerned by robotic production lines. As far as the workers at the 3D workshop (second workshop) are concerned, the tasks performed remain similar to the ones performed onsite but vary in terms of working conditions (see part 3.3) and in anticipation of the work processes as stated in part 3.1.

> *The work remains the same because we are still building houses, but the way of working is different because we are building houses that will be dismantled and shipped onsite to be rebuilt.* (interview excerpt, joiner)

As far as the drafters in the design office are concerned, they operate in a minority segment of their profession (3D prefabrication of timber frames). This implies proficiency in specific skills and the recruitment of corresponding profiles, for a profession whose scope of tasks is thus diversified and, according to the head of the design office, appreciated by the workers. Due to digitalisation of the production processes and the greater vertical differentiation that follows, the number of drafters hired by Mobic tends to increase over the years.

Skills

The company defines three levels of use for robotic lines and, more generally, for production machines (such as the speedcut). Each of these levels corresponds to different requirements in

terms of skills, as well as recruitment (see next section) and training (see dedicated section in part 3.2) practices. We also analyse these issues at the design office division.

As far as production is concerned, the first level is that of basic operator. This level of use of robots and machines corresponds to the day-to-day operations that have to be carried out in a functional working environment. The level of qualification required in terms of both technical and cognitive skills is low, and is "*actually excessively accessible, even to those who do not have a joiner's profile"* (interview excerpt, Mobic's founder). Focus is put on basic soft skills, *i.e.* motivation, seriousness, conscientiousness, etc. In that way, versatility in the day-to-day use of the various machines is increased in order to be able to make up for possible absences of workers. The second level is that of expert operator. It is expected from the expert operator to be able to detect problems as well as to analyse those reported by the basic operators. On the basis of this analysis, the expert operator determines if they are capable of direct repair in order to return to a normal production framework, or if the repair order should be passed on to maintenance. Such decision is taken according to the urgency of the situation (*e.g.* problem causes a production shutdown; production shutdown must be planned for fixing the situation; situation can be solved during off periods, etc.). It is therefore important to possess machine programming skills, as well as decision-making and planning skills. The third level corresponds to the maintenance vision. This level involves the R&D/maintenance departments of the three companies, depending on the machine and/or the type of problem encountered. Here, advanced technical skills in terms of programming, mechanics, engineering, etc. are expected.

As far as the design office is concerned, the design office manager considers that 3D prefabrication in the wood frame sector requires the mastery of additional specific skills for drafters. Drafters are required to understand as well as have a basic command of special techniques such as electricity, plumbing or heating. This can be explained by the fact that the production processes used in 3D prefabrication requires placement of these circuits beforehand, at the design stage (see "work processes and tasks" section in part 3.1). Therefore, the company favours architects profiles rather than designers to fulfil these functions, as the architectural education includes a section dedicated to the understanding of these techniques. As underlined by the design office manager, *"a designer will only draw. You need people who understand the project as a whole"*. Those skills are then improved over the years with experience or *via* specialists' consultation in coordination meetings.

Recruitment

As expected skills and tasks differ depending on workers' profiles, so do the companies' recruitment practices. This is particularly noticeable in the recruitment channel favoured for basic operators, on the one hand, and for the other types of profiles aforementioned, on the other hand. For basic operators, the preferred recruitment channel is through subcontracting. Several former basic operators worked under a salaried contract in Harzé, when part of the production was still located there. The merging of all production activities to Etalle led to the termination of those workers' contracts. Explanations given by the interviewees relate to the geographical distance

between Etalle and Harzé that made the daily commute a non-viable option. Currently, the majority of basic operators in production halls work through a subcontracting firm. However, exceptions exist: pre-existing internal contracts (*e.g.* transmission of salaried contracts with the takeover of the sawmill); very specific profiles of workers (such as the joiner we interviewed); commitments to internal employment contracts made with centre of expertise following the development of a training connected to a recruitment campaign. As regards the other types of profile mentioned, they operate as employees either with Scidus or Mobic companies.

Based on our interviews, we distinguish three reasons as to why the company resort to subcontracting for basic operators. Firstly, subcontracting facilitates the company's ability to manage variations in the number of simultaneous customer orders. Typically, the number of workers employed in production varies between 40 and 60 people. Numerical flexibility based on the volume of orders is therefore ensured. Secondly, management feels that subcontractors might show more motivation for getting work done as they are paid on a project basis (the more projects they finish, the more they get paid), in what can be called "*a carrot and stick"* strategy. Thirdly, in line with what Lepak and Snell (1999) suggest, contractual work arrangements are a fitted response to a situation in which both uniqueness of the skills and strategic value provided by workers are low. Digitalisation and the use of robotic production lines (V1 and V2) simplify 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. The company thus uses the market option rather than the salaried contract to acquire these skills. According to the opposite reasoning, the enterprise uses the salaried contract rather than the market option in order to maintain internally specific skills that are difficult to find on the labour market and that bring a high added value to the enterprise. The following excerpt about basic operators illustrates our analysis.

> *We have no problem ensuring that sufficient expertise is available. Tasks are carried out according to pre-established instructions. The outcomes of the robotic production lines is what makes our added value.* (interview excerpt, Scidus' director)

3.3. Impacts on working conditions

Training

The digital technologies implemented within the company lowered the needs in technical qualifications for basic operator. Once recruited, a strong focus is put on the on-the-job training in order for the basic operators to acquire the necessary technical elements to operate with the robotic lines. They relate, *inter alia*, to the ability to read 3D plans or to the correct positioning and manipulating of the tree trunks handled in the V2 in order to reach an adequate quality in the cuttings. Expert operators provide the training elements directly on the field in the form of one-off training points adapted to the problems faced. Learning by doing is also emphasized. The main objective is the correct use of the machine at its full capacity.

Training for expert operators is also given in-house, under structured form. The initial mastery of machine by the first expert operator is acquired in collaboration with the designers of the robotic

lines or external consultants. Subsequently, the expert operator is responsible for training other managers to reach this level, over periods identified and reserved for this purpose. By way of example, during the first week of January 2021, the founder of Mobic (expert operator on the V1) gave a training course to the assistant production manager on that matter.

Workload, work pace, autonomy and control

Digitalisation combined with the just-in-time production system results in a production organisation that seeks to maximise the operational capacity of the machines. The work pace and tasks are driven by standardisation of process through production orders by projects in order to achieve such maximisation. As previously exposed, the enterprise resorts to numerical flexibility via subcontracting in order to adapt the workforce to the amount of workload required. The *"carrot and stick"* strategy might question the workload intensification for workers, but we are unable to provide feedback from the field on that matter. Regarding autonomy, discretionary decision making as regards the speed of the machines cuts is possible by reporting speed adaptation demands to the assistant production manager. However, autonomy in the sense of the establishment of the own workers' rules in the organisational and production processes is very low. The main form of control lies in the close digital monitoring of work *via* production orders. Workers refer to the files on the machines in order to operate; and their achievements are checked during the day by the foreman and the assistant production manager (see "work processes and tasks" section in part 3.1).

Health and safety

Offsite production makes it possible to lower many risks traditionally encountered on construction sites, whether for the workers themselves or for others. Physical conditions at work are improved. The production halls provide adequate lightening and temperature and are less subject to climatic conditions. Working infrastructures (such as scaffoldings) can be appropriately placed as the ground is perfectly flat, and working tools are available within close range. Workers have access to standard amenities, compared to the often basic ones on construction sites.

> *We don't have to take into account the wind, the cars... We just have to look out for our own safety and that of the people who work with us. We don't have to worry about trespassing, for example…* (interview excerpt, joiner)

According to Scidus' director, these health and safety elements also constitute a key advantage for recruiting workers. The proximity of Luxembourg, offering higher wages with which Belgian companies can hardly compete, draws many worker to this country. Improved working conditions act as counterweight to this trend.

With regard to the interaction with the robots themselves, engineers at IMAX Pro have defined two security zones. The robot is notified of the presence of external objects by a series of sensors. If an external element enters its first working area, the robot adapts its working speed by slowing it down. Whenever that element trespasses the second zone, the robot stops, and then resumes work

once the zone is secured. This security aspects enhance workers' safety, according to management of the company.

4. Industrial relations and social dialogue

4.1. Within the enterprise

There are currently no structured and formal social dialogues bodies within Scidus or Mobic. Both companies are under the thresholds requirements (which relates in Belgium to the number of salaried workers) for establishing a trade union delegation, a health and safety committee or a work council. Hence, industrial relations in a broad way take place between direction and workers directly. Management has expressed during the interviews the desire of maintaining this direct dialogue with workers as long as both parties judged it appropriate. As underlined by one of our interviewees: "*the boat needs only one captain*".

Regarding the implementation of the digital technologies, the second robotic production line (V2) has reunited various actors for its conception and implementation: the employers, the knowledge workers from IMAX Pro as well as several university academics in robotics, engineering and wooden structures fields. No other actors such as unions' representatives at regional or national level, civil associations, etc. were involved.

There are no agreements (whether binding or non-binding) regarding the technological innovations and their possible impacts on work organisation, labour force or working conditions. Social dialogue about these topics is then informal and happens through management line. Workers are informed of the implementation and operation of the lines when relevant (e.g. spontaneous talks, first visit of production hall upon hiring, etc.).

On the specific topic of health and safety, prevention of occupational risks in ensured notably by visible placards informing workers of the ways machine works and the appropriate actions to take within its radius, such as which mandatory equipment to wear. Documents given upon hiring also specify by which security rules workers have to comply and which training certification the workers must possess before manipulating some machineries (such as a forklift) or setting up scaffolding.

4.2. Implementation and effects of the technologies on social dialogue in general

We provide one hypothesis as to how new technologies influence industrial relations and social dialogue on a macro level. As we exposed earlier, 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 the necessity to keep the related skills internally is reduced. Extending this reasoning, we postulate that digitalisation enables a deskilling of tasks, which, in turns, allows companies to resort to different subcontracting methods that it would not otherwise be able to use (without deskilling, enterprises could face a skill shortage regarding trades needed, which could

therefore be difficult to hire at subcontracting conditions). As the legal thresholds for the establishment of the bodies of social dialogue in Belgium relates to the number of salaried workers employed, their instauration is delayed in organisational configurations with a substantial part of subcontractors. In that way, the explosion of workers' statuses with digitalisation may poses a threat to social dialogue structures.

5. Drivers and barriers considering digitalisation

We identify several drivers and barriers considering digitalisation that can apply to the case studied and the sector. In term of drivers, firstly, the culture of innovations brought by the founders profoundly shaped the development of the companies towards digitalisation. As one of our interviewees stated, "*what is really surprising here is the determination and will of* [one of Mobic's founder] *to robotise the wood industry, when we don't necessarily think about robotising it*". Secondly, the strong focus put on internal R&D made it possible to adapt and tailor the digital innovations to the specific needs of the company. Thirdly, the implementation of the robotic production lines is as an answer to sector-specific problems such as the arduous nature of the work and the shortage existing for several years in the construction trades, especially on highly skilled trades such as carpenters (see national report). Fourthly, the additional production costs of wood construction compared to construction in concrete. This situation is caused by the high value losses linked to processing of wood. This pushed the company to turn to the JIT production system as a support to digitalisation, and to establish constructions plans that maximise the use of the wood and limits losses.

> *The sawmill can produce three types of length in the woods: 2m70, 3m30 and 3m70. These are short structural timber. Beyond these lengths, we have to buy KVH* [a type of wood available for sale] *of 13m in length. In the sawmill, short structural timber costs* [a given price] *per m3. KVH costs* [around three times this price] *per m3. [...] So we worked on the planning and the JIT to buy as little KVH as possible, and at the same time to not have to maintain an incredible volume of different woods.* (interview excerpt, assistant production manager)

Fifthly, environmental issues related to the imbalanced between the amount of trees planted in the country and the amount of trees cut for production. Digitalisation, especially the V2 of the robotic line, allows complex cutting and assembling techniques that significantly reduce the amount of wood needed for construction. It is one of the solutions that can be implemented to ensure sustainable forest management in which the quantities harvested annually do not exceed the growth and renewal capacity of the forest.

The greatest barrier in terms of digital industrialisation of the wood construction sector relates to the complete absence of parametric design softwares that have to be uploaded to the robots to carry out the cutting operations. Company therefore collaborates with universities on long-term research projects for the creation of such softwares. For companies in general, and based on the case studied, we consider that a certain size and a related volume of production must be reached in order for the

investment in such machines to be profitable. This is a major constraint since most timber operators are small enterprises (in line with the distribution of enterprises in terms of number of employees at national level). However, digitalisation can also be seen as a vector of growth for companies which supports companies' development. The robotic lines offered growth opportunities for the companies in terms of new markets and competitive advantage.

> *The image associated with robotising industry is often that of multiple layoffs. I think that this is a vector of growth. It is the tool that has enabled our factory to develop. We started with 4 people and now we are almost 150.* (interview excerpt, Mobic's founder)

Finally, as the wood sector is strongly fragmented, the necessary collaboration along the required actors supply chain is complex. The vertical integration strategy adopted by Mobic/Scidus may be an inspiring answer to this sectoral particularity.

Conclusion

This case study addressed the impacts of the introduction of robotic production on the organisational and social dialogue aspects of the sister companies Mobic and Scidus.
Regarding direct impacts, changes in terms of tasks handled by the operators is probably the most notable, as they switched from factory operators to machines workers. The substitution relation that happened in both V1 and V2 of the robotic lines simultaneously led to two different types of effects. On the one hand, an improvement of working conditions especially in terms of health and safety and drudgery of work. On the other hand, it generated a form of deskilling regarding the operators. Entry barriers for hiring workers are then lowered, as they can be trained more easily for the jobs. On the contrary, skills of expert operators, maintenance and drafters have been reinforced. As vertical differentiation increased with the production orders being elaborated by the design office, standardisation of process became the norm in the enterprise. The introduction of the V2 also opened up gates to new markets for the company, that would not otherwise have been reachable.

Regarding indirect impacts, we can cite the vertical integration strategy that is pursued by the company and materialised at both ends of the supply chain. On the one hand, via the takeover of the sawmill and, on the other hand, via the focus put on off-site prefabrication. Moreover, we believe that the modification of the production processes towards a just-in-time production system has been facilitated by the digitalisation of the company, and acts as a support to the technological innovations.

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 rom 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.

Future researches on the topic should mainly seek to involve machine operators direct feedback in order to enrich data regarding, for example, wages, possible working hours intensification or relation with the machine. On a larger perspective, at society scale, we raise our concern in this conclusion regarding the impact of the V2 of the robotic line on highly qualified technical professions. Machines are reaching level of precisions and sophistication that now enable them to perform non-routine manual work. Undoubtedly, the deployment of these machines will have an impact on occupations such as carpenter, in which a shortage of labour already exists for several years now. The question remains as to how and to what extent such jobs will evolve.

References

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