Digitalising the Construction Sector

Unlocking the potential of data with a value chain approach

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COMMITTEE FOR EUROPEAN CONSTRUCTION EQUIPMENT

I&D Consulting
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Strategie, Innovazione, Ricerca e Organizzazioni Srl
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Acknowledgments

We would like to thank and acknowledge in the first place CECE for launching such an ambitious research project on the digitalisation of the construction sector by adopting a global value-chain approach. We would like to acknowledge then the Steering Committee for the precious inputs and for the constant support and engagement all along the project phases. Finally, one special thank goes to the companies, the research centres and the associations whose collaboration and contribution made this project possible. Knowing that this is only a drop in the ocean, we believe that it is a starting point for further discussion on the subject.

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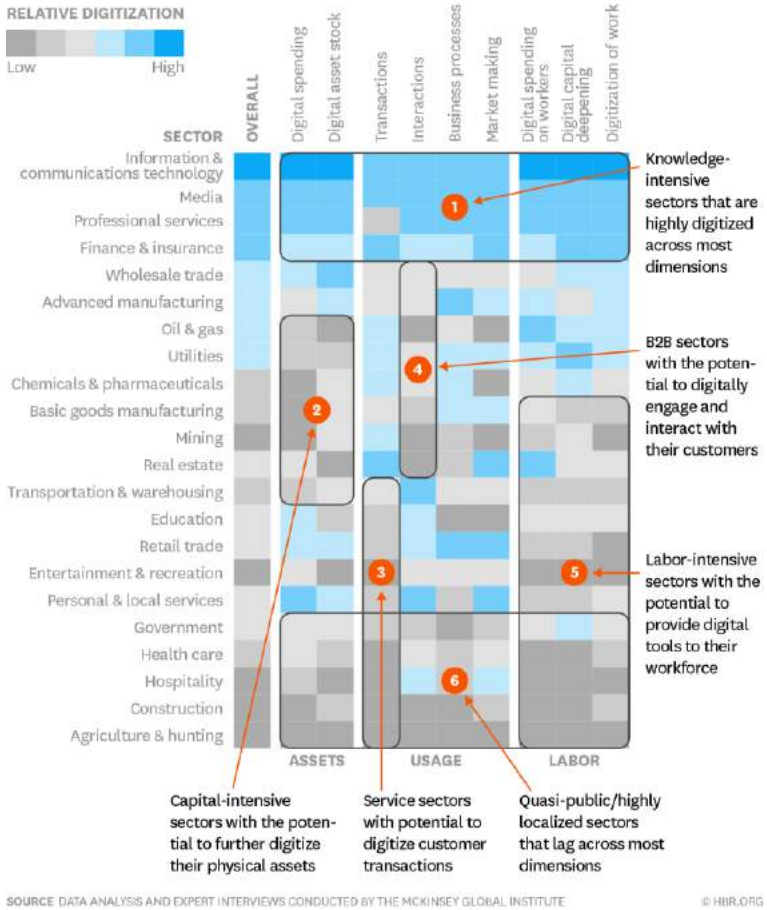
Introduction

The background

The construction sector is one of the largest sectors in the world. Construction-related spending accounts for 13% globally and the sector's total annual revenue is around $10 trillion globally with an expected increase of up to $14 trillion by 2025. The construction industry today employs over 100 million people and has one of the greatest economic spill over effects, representing an additional economic benefit of $2.86 for every $1 of construction GDP[1]. As a result, even a slight change in the sector will have huge repercussions on the fabric of the economy worldwide.

In terms of digitalisation, construction is still one of the least advanced compared to other sectors[2] (see image below) in 2017 only 7.7% of construction enterprises had a high or very high level of Digital Intensity Index[3].



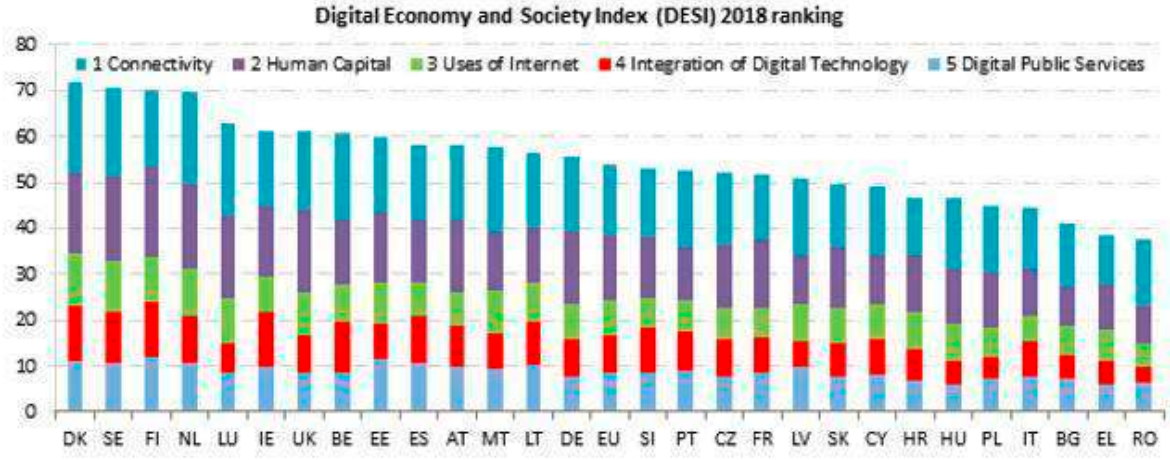
Source: P. Gandhi, S. Khanna, S. Ramaswamy, "Which Industries Are the Most Digital (and Why)?", Harvard Business Review, April 1st 2016

[1] Data derived from the McKinsey report "*Reinventing construction – A route to higher productivity*", February 2017.

[2] Data derived from the *Industry Digitization Index* elaborated by McKinsey in 2016.

[3] The **Digital Intensity Index** measures the integration of Digital Technologies by enterprises, assessing the availability at firm level of internet for at least 50% of people employed, the recourse to ICT specialists, fast broadband, mobile internet devices, website, social media, sharing supply chain management data electronically, the use of ERP software packages, the use of CRM, e-commerce web sales and B2C web sales).

This can be partly due to the fact that there are still significant differences in the level of digitalisation in Europe (as exemplified in the image below), but the construction sector is facing also other challenges related to digitalisation.



Source: Digital Economy and Society Index 2018, European Commission

Even though the sector is facing several challenges linked to the adoption of new digital technologies, evidence from the research shows that there is a growing awareness regarding the need to embrace digital change in order to increase the overall productivity and efficiency while also improving environmental sustainability and safety.

The project

Summary of the Report

The scope of the current research, promoted by CECE, is to conduct an enquiry into the digitalisation of the construction sector so as to gain a better understanding of the dynamics and evolution, addressing the changes triggered by new digital technologies. In particular, the present study is meant to provide the actors involved in the sector with a comprehensive picture of future trends in the new digital scenario.

Throughout the study, digitalisation is intended as a wider and more complex issue than the adoption of digital technologies per se: it means transforming businesses by leveraging the potential of digital technologies to create new revenue and provide higher value. The research thus adopts a complex and comprehensive approach analysing the risks and opportunities that stem from the adoption of digital technologies in the following areas (as exemplified in the image below): business models, relation with public authorities and regulatory bodies and skills and competences.

Source: ID Consulting and S.I.RI.O.

The project methodology

Considering the size and complexity of the construction sector, the research was conducted following a qualitative approach which combined the analysis of existing reports on the matter with interviews held with companies from across the construction sector (targeting OEMs, contractors, rental companies, dealers, IT providers and end-users) and the IT sector, as well as representatives from other sectors that are going through digital transformation (i.e. automotive, agriculture).

The identification and the selection of a sample of highly representative companies and case studies constituted one of the major challenges facing the research. To mitigate such risk, a Steering Committee was established bringing together representatives of OEMs, contractors and rental companies. The Steering Committee actively contributed to the project by helping identify suitable companies for the interviews and case studies, by revising questionnaires and by monitoring the overall research.

In order to fulfill the above mentioned objective, the research was based on the following sources (as exemplified in the image below):

Source: ID Consulting and S.I.RI.O.

Desk Research

To determine the actual level of digitalisation in the construction sector, the project examined existing reports focusing on the aspects related to the introduction of new digital technologies in the construction sector. The desk research proved to be useful in the elaboration of the questionnaire adopted for the interviews conducted with selected companies.

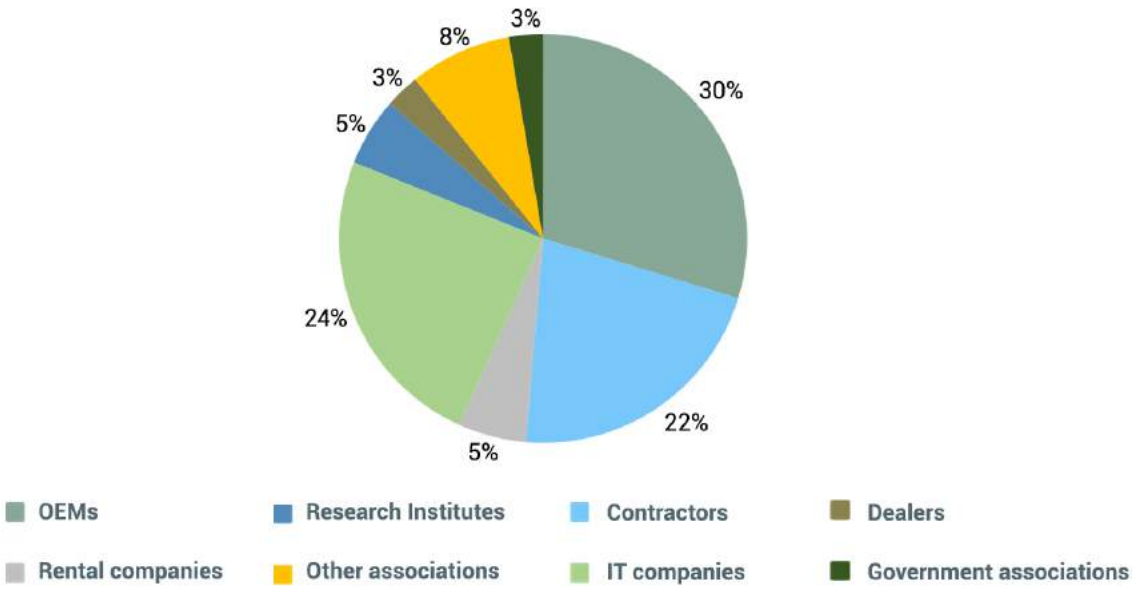
Online survey

In parallel, an online survey was released to kick start the project and to increase the number of potential interviewees. The survey saw the participation of 136 representatives from the construction sector (mainly OEMs and contractors) and the results are in line with those collected during the in-depth interviews.

In-person interviews

A series of interviews were carried out with representative companies across the construction sector (OEMs, contractors, rental companies), as well as other sectors that play a significant role in the digitalisation of the construction sector (i.e. IT players), so as to understand the perception of the various actors on the subject. The interviews were also conducted with members of other sectors that had gone through digital transformation in recent years (i.e. agriculture, automotive). The analysis considered elements such as: the impact of digitalisation on business processes, skills and competences, collaboration with other actors in the value chain, business models and market trends as well as regulation and the relationship with public authorities. The answers given during the in-person interviews were completely anonymous.

As exemplified in the chart below, the interviews were conducted on a sample of 47 people from 37 companies. Of these, the majority were OEMs, followed by 24% of IT players and a 22% of contractors.



Source: ID Consulting and S.I.RI.O.

Practical case studies

The case studies identified were thoroughly investigated by adopting an ecosystem approach to better understand the level of digitalisation accomplished, as well as the dynamics of the digital transformation in the context of the construction value chain. This method allows for the breakdown of potential silos and a broad and comprehensive view on the phenomenon. The results derived from the analysis of the selected case studies proved to be valuable in the drafting of the final results.

Summary of the project

Chapter 1 starts with a definition of the term "digitalisation" in light of the answers received from the companies involved in the project. Evidence shows that data is considered the most important element of digital transformation. The adoption of digital technologies can bring substantial advantages thereby increasing the overall added value of the sector. However, there are still barriers that might slow down the digitalisation process if not correctly addressed.

Chapter 2 is focused on the new business models that are triggered by the adoption of the new digital technologies. Drones, IoT, sensors, robotics offer great opportunities, not only in terms of digitalising construction processes to make them more efficient and sustainable, but also in terms of improving the products and the services that a company is able to deliver to its clients. Thanks to data collection and analysis, companies gain insight on the whole ecosystem, working towards clients' needs and providing the solution, instead of providing the product per se. This means that trends such as servitization and customization will gradually gain momentum. Collaboration and data sharing between companies will be crucial for gaining the wider view on processes and clients' needs and data protection and cybersecurity, as well as new forms of data sharing models must be taken into consideration, offering ways to share data in a "win-win" perspective and overcoming potential risks that may arise from opening data to other actors.

Chapter 3 concerns the relationship between public authorities and the construction industry. Being one of the industry's main clients, every step that a government takes in support of digitalisation can generate a significant impact on the digital transformation of the sector. Indeed, governments are able to stimulate the adoption of digital technologies in public-funded projects and favour the "Best Value for Money" approach, as well as to support companies in terms of taxation and provision of grants. Governments can also play a role in reshaping education, by collaborating with construction companies and academia to the design of trainings on the useful managerial and digital skills for current and future employees.

Chapter 4 introduces the fact that digitalisation will change the labour market in the years to come, not only in terms of digital skills needed to work with technologies and manage data all along the value chain; but also in terms of managerial and executive skills needed to lead companies in such a scenario; digitalisation indeed makes companies rethink themselves to better respond to the current needs as well as to position themselves in such a changing market. Not only that, on the one hand digital technologies supports operators doing repetitive tasks with the consequence of having more high skilled employees, on the other hand there will be an increasing need of "simplified" jobs (i.e. the machine will drive itself and the operator will be there only to overcome visibility issues); this will result

in a greater gap between high level and low level jobs. Given these changes, companies will have to put efforts in training, considering collaborating with governments and academia.

Chapter 5 gives an overview of the digitalisation trends that are occurring in two sectors, agriculture and public and commercial vehicles, providing a comparative analysis with the construction sector to identify the elements that may be taken into consideration when performing such a shift.

Chapter 6 provides a glimpse into the process that companies may adopt when facing digitalisation. Starting from the identification of the enabling factors that need to be in place for digital transformation to happen, companies need to set up the strategy considering elements such as the ecosystem in which they are operating in, identifying the value position and the consequent technological solutions and organizational changes, in view of designing the business model blueprint that will lead the company to "digitalise" successfully. Then, the model blueprint will have to be implemented and turned into a working business.

Chapter 7 presents practical case studies coming from the sector. These latter have been deeply investigated to understand the challenges they were facing and the related solutions, highlighting the elements that made the solution a success and the barriers that occurred when implementing it. From the case studies a series of lessons learned have been extracted, these were useful to draw the roadmap of the future of the sector and draw the conclusions presented at the end of the report.

The conclusions give an overview of what has been said in the previous chapters. This final chapter ends with a a series of recommendations in order to accelerate the digitalisation process in the sector and to provide companies with guidelines to thrive in such a changing scenario.

1. Digitalisation: meaning, impact and barriers

1. Digitalisation: meaning, impact and barriers

1.1 Meaning

Providing a unique and exhaustive definition of the term "digitalisation" is not an easy task. In the context of this research, we started from the Gartner IT Glossary definition: "digitalisation is the use of digital technologies to change a business model and provide new revenue and value-producing opportunities". We could add that digitalisation goes beyond the mere adoption of digital technologies, given that it has more to do with the role they play in reshaping organizations, processes, products and services.

Evidence resulting from the analysis of the interviews shows that the majority of the companies involved in the project generally agree with Gartner's definition of digitalisation. The responses clearly show that digitalisation means improved communication, higher efficiency in managing construction processes, better communication between machines, but also higher sustainability and improved safety thanks to a better use of resources that is made possible by the use of new technologies. However, one recurrent and critical element was identified: data. Digitalisation means accessing information to gain insights and leveraging the "power of information" that stems from the collection, analysis and management of data to provide new solutions with a higher value added. Data can be considered as a cross-cutting issue that is closely connected to the enabling technologies that stand behind the digitalisation process.

The results also show that the introduction of digital technologies entails rethinking the way companies are structured and have been operating while adopting a more comprehensive approach that foresees new forms of collaboration with other actors along the value chain with the aim of extracting the highest possible value from re-designed digitally-enhanced processes. In that sense, the increased ability to collect, analyse, integrate and use data derived from several sources (i.e. geographic information systems, cyber-physical systems on construction equipment, weather data, drone aerial photography systems, mobile devices and tablets) contributes to a higher level of transparency between actors thus leading to a substantial improvement in the management of construction sites thanks to closer collaboration.

According to most of the companies, digital technologies have the potential to result in significant advantages in a series of tasks related to construction activities, as exemplified in the table below.

Task	Enabling technology	Result
Intelligent design and planning	BIM, Significant Data	Reduction in design errors and enhancement in the quality of the design and engineering processes through virtual and digital simulation (i.e. digital twin).
Fleet management	Internet of Things, Big Data	Remote monitoring through the use of sensors and analytics of status and location of construction equipment (i.e. work vehicles) so as to reduce costs, improve energy efficiency and limit idle time of machines.
Predictive maintenance	Internet of Things, Big Data, AI	Monitoring of the condition of machines through the use of sensors and analytics with the aim of conducting preventive maintenance and to reduce potential failures.
Innovative fabrication methods	Internet of Things, Big Data, AI, BIM, Drones	Rethinking construction processes and operations in a "smart perspective" leveraging the information gathered through data collection and analytics to speed up processes, reduce costs, improve energy efficiency and operators' safety.
Monitoring and Evaluation of Resilience	BIM, Internet of Things, Big Data, AI, Drones	Better "real-time" surveying in all of the phases of the project such as providing adequate support to on-site operators as well as monitoring resilience of infrastructure following the end of the project.
Autonomous equipment and driverless vehicles	Internet of Things, Big Data, Robotics	Introduction of driver-assistance systems and autonomous driving to improve construction processes and reduce physical workload on the construction site.

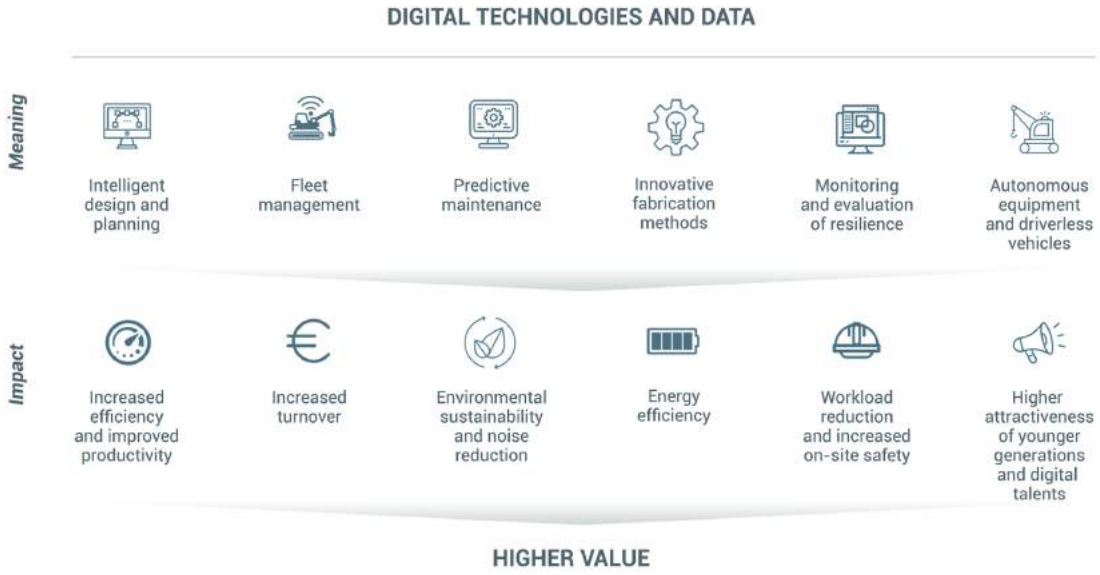
1.2 Impact

From the analysis of the interviews, it is clear that the adoption and use of digital technologies will impact the construction sector in many ways.

Increased efficiency and improved productivity	Thanks to digital technologies and automation companies can provide better products or services with fewer resources. Data analysis plays a central role in this, resulting in an in-depth understanding of the ecosystem to optimize processes and the use of machines.

Increased turnover and higher profits	Extensive use of digital technologies to monitor construction processes in every phase can lead to a better management of resources resulting in a reduction in costs and an increase in profits. Moreover, most of the companies interviewed see digitalisation as a mean of increasing turnover thanks to enhanced productivity and higher customization.
Environmental sustainability and noise reduction	The use of digital technologies (in particular data analytics to improve construction processes) might lead to the adoption of new solutions that improve environmental sustainability (i.e. an improved use of resources and the shift towards hybrid or electrified machines – where needed – can lead to a significant reduction in CO_2 emissions and noise).
Energy efficiency	Digital technologies can result in a consistent reduction in waste (i.e. fuel, electricity, water), consequently improving energy efficiency throughout the construction phases.
Workload reduction and increased on-site safety	Digital technologies such as automation and building techniques like offsite production result in a reduction in physical workload and exposure to dangerous activities on-site.
Higher attractiveness to younger generations and digital talents	The majority of interviewees believes that digital technologies have the potential to make the sector more attractive to young people and digital talents.

In summary, every actor in the value chain sees the potential of reaping the benefit from digitalisation that is generally considered a fundamental enabler in the transition to a high added value model, as shown in the image below.



Source: ID Consulting and S.I.RI.O.

1.3 Barriers

Large companies tend to be slow in taking decisions, but they can act as trend-setters in the future digital scenario

Because of the size and the complexity of decision-making, digital transformation in large companies can take a long time – sometimes in excess of three years, according to some companies. Having said that, they are usually well aware of the advantages linked to the adoption of the new digital technologies. Moreover, some companies have an interest in becoming trend-setters (i.e. for interoperability, data formats and communication protocols) in the new digital scenario, consequently showing their intention to improve their market positioning in the medium/long term.

Cost of digitalisation is relatively high for SMEs

Digital transformation is particularly burdensome for construction SMEs because of the high cost of the initial investments in the adoption of new digital equipment and technologies. This element is particularly relevant if we consider that sometimes the potential of digitalisation is not immediately evident and the return on investment is not clear. In the absence of a clear business case, SMEs are reluctant to digitalise their businesses. However, various forms of public support (i.e. grants, tax breaks etc.) to companies that adopt digital solutions appear to be promising tools that incentivise digital transformation amongst SMEs in the construction sector. In addition, forms of public and private (i.e. from large companies) investments in education and campaigns aimed at increasing awareness about the advantages of adopting the new digital technologies can play a positive role.

SMEs fear potential drawbacks resulting from the adoption of digital equipment

A number of SMEs are afraid of not having the right skills and competences to oversee the maintenance of fully digitalised equipment. Therefore, rather than losing their independence to a third party (i.e. OEM, IT Company) they prefer to stick to the old model. Moreover, because of the introduction of the driver-assistance systems and autonomous driving system, the operational skills of the operators will become less crucial and as a result they could decide to resist change due to the fear of losing their jobs.

The different level of maturity between large companies and SMEs is an obstacle to digitalisation

On most construction sites, large contractors rely on the work of several SMEs in the role of subcontractors. The gap in the level of digital maturity between large companies and SMEs might represent an obstacle to the creation of a fully digitalised construction site. In general, large companies tend to be more digitalised than SMEs. However, the picture is more complex. SMEs are in fact very flexible, and they adapt quickly to change, especially if correctly incentivized. In fact, they can even have a pull-effect on large companies thereby stimulating and accelerating the innovation processes – i.e. large companies sometimes create "parallel start-ups" so as to speed up innovation processes (for further information see Chapter 3, New Business Models)

Evidence from the interviews shows that when contractors and OEMs provide SMEs with ad-hoc training on the use of digital technologies, digital transformation occurs at a faster pace and potential gaps are quickly filled. Also, a change in the procurement strategies to make the use of digital

technologies compulsory (i.e. BIM) in the construction sector can foster digitalisation among SMEs, especially if coupled with financial incentives (i.e. tax breaks).

Lack of skills and difficulties in recruiting young people and digital talents

All of the companies interviewed agree that the sector lacks a series of skills that will be fundamental in years to come. This includes not only technical skills such as data analysis but also skills like leadership and management. Moreover, there is a consensus that digitalisation will cause a gradual shift in the internal organization of human resources. On top of that, the sector already suffers from a shortage of workers because of its low appeal as it is still considered "dirty, dangerous and dull." However, the shift towards a digital scenario might reverse this trend (for further information see Chapter 5, Skills and Competences).

Lack of commonly agreed standards and low interoperability

For most of the companies that comprise the construction sector, the lack of commonly agreed standards and low interoperability represent an obstacle to digital change. In particular, customers with mixed fleets are reluctant to buy digital equipment because they can't properly evaluate and compare performance due to the absence of commonly agreed communications protocols for data exchange. Efforts are being made both in the CEN and ISO Committees to find a solution to this (for further information see Chapter 3, Relations with Public Authorities).

2. Business models

2. Business models

2.1 Business models and the value of data

As already stated in the previous chapter, the adoption of new digital technologies is perceived to bring considerable advantages to the construction industry for several reasons (see image below)

Source: ID Consulting and S.I.RI.O.

Firstly, digital technologies offer great opportunities for improving products and services. For instance, IoT technology, on the one hand it can help monitor the condition of equipment to understand when maintenance should be performed thereby avoiding sudden and unexpected stops. On the other hand, having access to information about machine performance can open the way for product innovation (i.e. in terms of energy efficiency, lifetime).

Digitalisation also means higher customization: following clients' needs and expectations through data analysis it is possible to innovate and customize their products and services according to the inputs coming from the market. From this perspective, new forms of online support and post-sale services tailored to customer needs are emerging.

Finally, thanks to the use of digital technologies construction processes will be increasingly digitalised. On the jobsite of the future everything will be connected (i.e. construction machines, operators, drones, other vehicles) and data from the construction site will be stored in a cloud platform for further analysis, opening the way for the creation of new integrated products, services and support solutions across all phases of a project.

The majority of companies interviewed are aware of the fact that having access to such data will be crucial in improving overall construction processes. In order to achieve this goal, new agreements on data sharing will have to be introduced so as to fully reap the benefits of data. Furthermore, digitalisation is also pushing companies in the sector to rethink the way they are doing business: in particular, business models are expected to change and new forms of collaboration will emerge as a consequence of the adoption of digital technologies.

The servitization trend

Servitization

Servitization is the shift from providing products to providing product-centric services which *"deliver value in use"*. The integrated product-service can go from a "base service" (selling the product alone) or an "intermediate service", offering repairing of products, monitoring of the condition of such product, etc., to get to the "advanced services" such as *"Pay Per Use, Fleet Management, Availability Contract and Integrated Solution"*. (**Dr. Howard Lightfoot, manager of Operations Excellence Institute at Cranfield University**)

Servitization is considered to lead to major changes in the company structure and processes, innovating them to *"better create mutual value through a shift from selling product to selling Product-Service Systems"*. (**Professor Andy Neely, Cambridge University**)

Servitization is found to be successful when accompanied with digitalisation and in particular with data analysis. The use of connected technologies and the results stemming from complex data analysis can lead to major improvements in "use, maintenance and repair actions", knowing the product in relation to the specific client needs.

An important aspect of servitization is that combining products with services means providing a solution that is based on the outcome that the client wants to achieve: "selling 'holes' rather than drills; the customer wants to make a hole; the use, condition, features and performance of the drill is just a way of achieving that outcome, but isn't what the customer wants to concern themselves with"[4]. Working towards the solution instead of working to provide the product per se means having the client not just pay for the machine but rather for the complete solution to their problem: the client purchases a product and along with that receives services such as maintenance and support to reach his/her ultimate goal. This means that the provider of the solution must be able to determine a priori the cost of the solution, establishing an "outcome based contract." Again, information derived from data analysis is key: moving towards a servitized outcome-based business model means monetizing services that can be offered to the client and leveraging the potential of data analysis to succeed. As an example, rental companies can leverage on data gathered from the usage of machines (i.e. location, idle time, energy efficiency, kind of environment) in order to shift to a pay per use/per outcome model for a specific task to be performed on-site – such as moving a specific amount of earth on the jobsite.

Searching for a business case

The results clearly show that finding the right business case is the most important trigger for digital transformation. Before facing the challenges of digital transformation, most companies want to see a clear return on investment. However, at present the economic potential of digitalisation is not fully understood and from the analysis of successful cases of digitalisation it is not that easy to understand in what measure improvements were directly linked to the introduction of digital technologies. The cost of buying highly digitized equipment might be considered too high by contractors – especially smaller

[4] Baines, T. *Towards a Common Definition of Servitization* (2016) Aston Business School **https://www.advancedservicesgroup.co.uk/single-post/2016/07/05/Towards-a-Common-Definition-of-Servitization**

ones – if benefits cannot be clearly identified. That's probably one of the reasons why producers of small digitized machines have encountered less resistance, because of the lower risk involved in the investment.

That being said, all the companies interviewed are conscious that digitalisation can bring significant benefits to their organizations from an economic as well as of environmental sustainability and safety point of view. In addition, from the analysis of case studies it emerges that once companies have taken the first step in digitalising their business, there is no turning back.

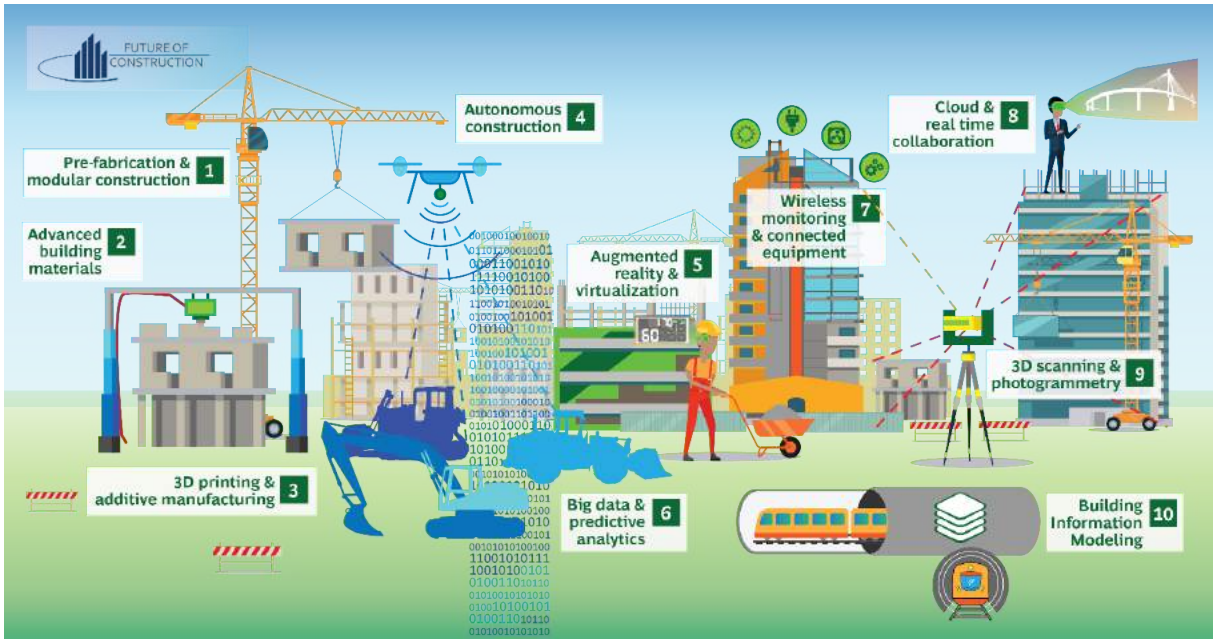
Extracting value from data

As affirmed by the Vice-President of the European Commission Neelie Kroes in 2012, "Data is the new oil for the digital age." In order to better understand the benefits of digitalisation, particular attention should be paid to the importance of data analysis as a tool for:

- analysing potential problems and needs on the jobsite;
- providing highly customized solutions to the customer;

From the analysis of the interviews and of case studies, it emerges that data analysis can be beneficial in many ways:

1. Data collected from sensors can be used to analyse machine performance for ad-hoc services such as predictive maintenance and fleet management, as stated above in the paragraph on "the servitization trend."
2. The collection of large datasets on processes and operations on the building site might help better investigate problems and inefficiencies on the construction site (see image below), thereby leading the way for the provision of new ad-hoc solutions.



Source: Future of Construction, World Economic Forum, Boston Consulting Group

By collecting, integrating and crossing data regarding all of the activities on the construction site, it will be possible to identify potential weaknesses in all phases of the construction process – i.e. design and planning, implementation, logistics, and energy consumption. Data (cloud) platforms are the main instrument where all data such as topography, materials, manpower, and construction equipment can be uploaded for further analysis. In that sense, the extensive use of BIM can greatly contribute to the overall improvement of operations onsite thanks to the superior monitoring possibilities of the project. Also, methods such as the Monte Carlo Method[5] can be used to better investigate the dynamics of the construction site and evaluate possible solutions. Finally, Artificial Intelligence (AI) represents a strong tool for the analysis and the use of site data with the aim of creating new and innovative business solutions.

In conclusion, having access to data and knowing how to manage it is a fundamental precondition for new opportunities to arise (for further information, see paragraph "Data Sharing: risks and challenges" below).

▸ *New forms of collaboration and management systems*

The analysis of the interviews shows that digitalisation results in closer (or different) forms of collaboration among the various actors all along the value chain. Following what has been said in the previous paragraph, the ecosystem approach is the key to exploiting the benefits of data analysis and providing innovative solutions to improve processes and operations onsite along with enhancing environmental sustainability and safety. As a result, closer collaboration among OEMs, contractors, rental companies as well as IT companies is gradually becoming the norm, as shown in a consistent number of case studies.

Because of digitalisation, boundaries between the different players' business are gradually blurring, opening the way for new forms of business management – for instance, rental companies may be interested in gradually moving into logistics while some OEMs are already providing rental services to their customers. Furthermore, large companies show a tendency to create new start-ups (especially in the IT field) that are much more flexible and that can easily strike deals with potential customers and partners so as to develop new solutions (see the box below) while avoiding legal problems.

The "parallel" start-up

In his book "The New Oil", Arent Van't Spijker describes the parallel start-up phenomenon as a startup created by a company to develop products in different markets. This start-up is managed and operates independently but, in a way, that the "common interest between the parent company and the start-up is managed for maximum benefit". The parallel start-up can leverage key resources (data) of the parent company and it has proven to "leverage innovative business models from existing companies".

[5] According to the Collins Dictionary, the Monte Carlo method can be defined as a "*an heuristic mathematical technique for evaluation or estimation of intractable problems by probabilistic simulation and sampling.*"

In conclusion, some of the interviewees, especially from the IT side, put the emphasis on new forms of management such as "squadification" that could be adopted in the construction sector.

Squadification

Squadification can be described as a system where small cross-functional teams ("squads") with a clearly agreed mission (i.e. increasing sales or creating a new product) work for the fulfilment of specific objectives whose metrics are clearly defined. Squads have no boss but only "product owners" without real enforcement power that supervise the activities. Squads can count on the work of an "agile coach" who acts as a facilitator. Squadification can be seen as a form of decentralized decision-making that increases responsibility and involvement in the firm's activities at different levels of the organization.

Data sharing: risks and challenges

As data is considered the *new oil of the digital age,* finding the right agreements on data sharing is becoming more and more important. However, there are still significant issues that need to be solved. For instance, some companies are reluctant to share data for fear of losing their know-how to the advantage of other players, thus running the risk of becoming commoditized. Some players (especially medium ones) believe that IT companies could erode part of their market share if data is not adequately protected – in particular, this is considered to be true in those segments characterized by repetitive tasks. However, consensus is not unanimous for several reasons. The most relevant being that OEMs and contractors are capital-intensive companies with a significant know-how, which represents a strong barrier to entry. As a result, they don't see such a risk to be a reality.

On the contrary, OEMs, contractors and rental companies are increasingly partnering with IT companies. On the one hand, IT players are directly bringing tailor-made digital solutions (hardware, software, mobility technologies) to various actors of the construction value chain – solutions such as:

- 3D laser scanners and 3D laser scanning software to acquire, analyse and visualize data from the construction site and inaccessible places from a safer space
- machine control systems integrated in machines to manage the fleet
- telematics devices and apps to monitor stocks of material and support logistics.

On the other hand, OEMs, rental companies and contractors have an interest in establishing fruitful partnerships and/or joint ventures with IT companies to integrate high quality components in machines and in the jobsite, thus improving their ability to create new data-driven services while having access to a wide array of data that can be useful in improving their operational capacity. Such partnerships might also lead to the design of new products/services that are a mixture of various solutions – i.e. data platforms that enhance the use of digitally equipped machines onsite.

In any case, data sharing will remain a very sensitive issue until problems such as intellectual property, data management, data governance are solved. Businesses will indeed increasingly rely on digital networks and infrastructures and, as a consequence, the risk of cyber attacks and their effects on the companies ability to deliver products and services properly will be always more considerable (see box on cyber security below).

Cyber security

Cyber security is the set of technologies, procedures, measures and techniques designed and put in place to prevent and protect computers, networks, programs and data from cyber attcks accomplished with the aim of exploiting them. Cybersecurity can cover the area of information security, providing measures aimed at preventing unhautorized access and protecting privacy or it can protect the network and its usability, reliability, integrity and safety.

Industries should commit to put in place processes that foresee the "investigation, triage and resolution of vulnerabilities, regardless whether the source of potential vulnerability was external or inside the company concerned" (EU Commission, JOIN(2017) 450 final "Resilience, Deterrence and Defence: Building strong cybersecurity for the EU").

To avoid such vulnerabilities, data security, data protection and access permission control must be taken into account when opening and sharing data.

To overcome the overlap of interests that could potentially emerge, some models of data sharing and data management are being set up both in the construction sector as well as in other sectors.

2.2 Models for data sharing

As previously stated, having access to data seems to be a precondition for new business opportunities to emerge. Every actor in the value chain is interested in accessing data for different reasons. Therefore, in order to reap the full benefits of data, new forms of data sharing between the actors in the value chain must be found.

This chapter takes a look at the models developed so far to manage data sharing among different companies, with a view to other sectors too.

The view of the European Commission

According to European Data Market Study, the data economy in Europe double by 2020 if the right framework conditions are put in place.[6] The European Commission is aware of the problems related to the ever-increasing amount of non-personal data generated in an automated process based on emerging technologies (i.e. IoT) and their use (or re-use). Data sharing in business-to-government (B2G) and business-to-business (B2B) relations is still a topic under discussion. In particular, B2B and in the absence of horizontal legislation[7], data sharing among businesses has up to now been regulated by bilateral contracts between the parties. These types of contracts contain details such as: duration, value of the contract, types of data to be exchanged, access rights, type of data usage, technical aspects for data sharing, data protection etc. From the technical point of view, data sharing can take different forms; one of them is the Digital Industrial Platform.

Digital Industrial Platforms are considered key in placing Europe at the forefront of digital

[6] COM(2018) 232 Final, *Towards a Common European Data Space*

[7] The European Commission however lists a series of key principles such as transparency, shared value creation, respect for each other's commercial interests, ensure undistorted competition and minimised data lock-in to be respected for a fruitful collaboration.

transformation, as they represent the bridge between technology building blocks on the one hand and industrial applications on the other. Equipped with appropriate business models, Digital Industrial Platforms may ultimately be instrumental in the creation of ecosystems of market actors in a multi-faceted marketplace. These ecosystems enable the creation of new innovative products and services and accelerate the development of worldwide standards.

Digital Industrial Platform

According to the European Commission, digital industrial platforms are widely seen as a strategic requirement for Europe to master new and changing value chains as well as trigger the digitalization process in several sectors. In particular, the creation of next-generation digital industrial platforms for the secure sharing of proprietary industrial data and personal data is financed through the Horizon 2020 Programme. Such platforms are conceived as operating systems that integrate different technologies, applications and services. They open up data from e.g. the machines, products and operators on a shop floor, make it accessible to e.g. monitoring and control applications, may provide open interfaces that allow third parties to develop applications on top, and connect different stakeholders, such as users and application developers. Such platforms integrate data from various functions implemented by different technologies via clearly specified interfaces and makes data available for use by applications.

Code of Conduct for data sharing in agriculture

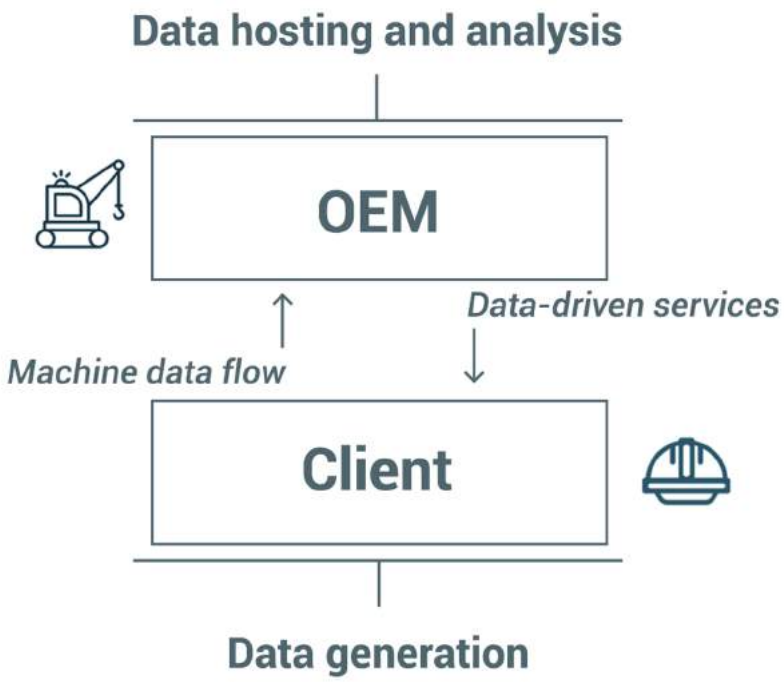
The problems related to data sharing and data management are not limited to the construction sector. Examples of possible solutions could be taken from other sectors. An example is represented by the EU Code of Conduct on Agricultural Data Sharing by Contractual Arrangement agreed by Copa and Cogeca, CEMA, Fertilizers Europe, CEETTAR, CEJA, ECPA, EFFAB, FEFAC, ESA that was launched in Brussels on April 23rd, 2018. The Code of Conduct contains a series of non-binding principles on the rights and obligations of accessing, (re)using and sharing data and they are reflected in contractual agreements between the parties. The document predominantly focuses on non-personal data and defines guidelines on the following elements:

- data ownership;
- data access;
- control and portability;
- data protection and transparency;
- privacy and security;
- liability and intellectual property rights.

The Code of Conduct is voluntary, and it serves the purpose of boosting transparency and trust among the participants leading to new business opportunities. An important point to emphasise is that data originators have a leading role: in controlling the access to and use of data from their business, in deciding to transmit or not their data to another data user (portability of data) and in benefiting from sharing the data with any partner they wish.

The "Banking Model": an example for data sharing in the construction sector

CNH adopted an innovative model that favours data sharing between OEMs and contractors/data owners that is similar to a "Banking Model". The latter works as follows: the OEM provides the customer with a digitally equipped machine that can collect a wide array of data about its functioning and usage; when signing the contract, the customer has the right to sign a legal disclaimer that establishes which data can be accessed by the OEM and for what purposes (i.e. monitoring and predictive maintenance, energy consumption analysis).



Source: ID Consulting and S.I.RI.O.

Legal ownership of data stays in the hands of the customer as he is considered the originator of the data. The originator of the data is the only subject that can decide what to do with his data (i.e. granting access to third parties). The OEM hosts the customer's data that is analysed in order to improve the efficiency of the product. In exchange for the right to access data, OEM provides the customers with data-driven services that are linked to the results of data analysis.

3. Relationship with public authorities

3. Relationship with public authorities

The analysis of the interviews shows that the success of digital transformation is closely related to the role public authorities and governments play in the process for several reasons. It's worth remembering that the public sector has a clear influence on the construction sector given that public procurement accounts for a major share of total construction expenditure worldwide, making governments one of the industry's main clients (i.e. 31% in the United Kingdom, 44% in Germany and 57% in the United States)[8]. Therefore, every step that a government takes in support of digitalisation can generate a significant impact. For instance, measures such as the obligation to adopt digital technologies in public-funded projects, forms of financial support to digital transformation (i.e. tax breaks, grants for purchasing new digital machinery), not to mention the difference supporting the education system can make in promoting digital transformation in the construction sector.

3.1 Public procurement

Results from the interviews show that a significant majority believes that governments can enable digital transformation in the sector by mandating the adoption and use of new digital technologies in public procurement procedures (i.e. the use of BIM in public works contracts).

What is Building Information Modelling?

The European Commission supported the establishment of the EU BIM Task Group, a pan-European collaboration of public sector organisations across 21 countries aimed at developing common principles for public authorities to introduce BIM in their public works or strategies. In their "**Handbook for the introduction of Building Information Modelling by the European Public Sector**" the EU BIM Task Group defines BIM as "a digital form of construction and asset operations" which "brings together technology, process improvements and digital information to radically improve client and project outcomes and asset operations. BIM is a strategic enabler for improving decision making for both buildings and public infrastructure assets across the whole lifecycle. It applies to new build projects, and crucially, BIM supports the renovation, refurbishment and maintenance of the built environment – the largest share of the sector."

The Handbook also reports that there are projections that the wider adoption of BIM will unlock from 15% up to 25% savings in global infrastructure by 2025. If the widespread adoption of BIM across Europe "delivers 10% savings to the construction sector then an additional €130 billion would be generated for the €1.3 trillion market." Not to mention the significant impact that it would have at both social and environmental level.

[8] World Economic Forum, "Shaping the future of construction – A breakthrough in mindset and technology", May 2016, pag.47

In this sense, the European Union in 2014 approved Directive 2014/24/UE (EU Public Procurement Directive), which recognises the benefit of BIM to the public sector in generating greater value for money (in public works) and in encouraging innovation. The directive has encouraged public procurers across Europe to consider the introduction of BIM, creating a need for information on BIM from the European public sector.[9] According to the Directive, EU Countries may require, specify, promote, or mandate the use of BIM in construction projects financed by EU public funds. This Directive was published in the Official Journal of the European Union on 28 March 2014 and came into force on 17 April 2014, date from which countries had two years to implement it. Efforts are ongoing to promote the use of BIM in the EU, however for the time being, differences continue to persist among Member States. According to some interviewees, the UK model is used as best practice regarding BIM implementation in public procurement.

Case study: UK Construction 2025

The UK Government and the construction industry set up a joint strategy in the framework of "**Construction 2025**" (2013) to push the industry forward. One of the aspects included in the framework concerns the implementation of BIM, considered to "improve sector productivity and lower costs due to improved information flow and greater collaboration". The joint industry and Government Building Information Modelling (BIM) strategy envisaged that by 2016 all Government construction projects will be using BIM level 2 (see table below) and that between 2016 and 2025 the government and industry will gradually move to BIM Level 3. This latter must go hand in hand with "the further development of technologies and commercial models and promises enormous benefits through delivering fully transparent data sharing capabilities across the supply chain." In the Government's pilot BIM schemes framework is the Manchester Town Hall Building project, which delivered significant results in terms of money and time saving (nine months were saved thanks to the implementation of BIM).

There are other examples of EU countries that created their own BIM mandate, "The German government will request a mandate for public infrastructure projects by 2020. Spain has a BIM Commission sponsored by the Ministry of Public Works to implement BIM in buildings in 2018 and in infrastructure in 2019 (McAuley et al., 2016). Denmark will have a mandate for all projects in 2022"[10]

BIM Level 0	There is no collaboration in the project and the output is delivered via paper or electronic documents.	This level has already been surpassed by the construction industry

[9] EU BIM Task Group, "Handbook for the introduction of Building Information Modelling by the European Public Sector", 2017, page.11.

[10] Azzouz, Ammar & Hill, Paul & Papadonikolaki, Eleni, *Digital innovation in Europe: Regional differences across one international firm*, 2018, page 241.

BIM Level 1	CAD (Common Data Environment) and 3D modelling tools are used but the digital collaboration is limited.	Currently the most used BIM.
BIM Level 2	Level 2 is characterised by collaborative working between parties using 3D CAD models. Each party works from individual models which combine with external data from other parties to create a "federated" BIM model.	This is the minimum BIM level mandated by the government for all public contracts.
BIM Level 3	BIM Level 3 aims at digitising the whole life-cycle (the entire project model is stored in a centrally-based repository) and establishing a strong collaboration among the actors involved	Not fully deployed yet

*Source: International experiences: **Future Cities and BIM – Final Report**, Department of Economy, University of Cambridge*

BIM turns out to be an effective tool for construction project planning, but according to one interviewee this digital tool should be extended beyond the design and implementation phases by also deploying it in the upgrading and maintenance of existing ageing buildings. Upgrading and maintenance operations are mostly done in a non-digital way and still account for a large part of construction operations.

However, the spread of BIM within companies is far from an easy process due to the fact that it requires a considerable increase in ad-hoc expertise as well as appropriate employee training and substantial IT upgrading. As a result, the adoption of BIM especially among SMEs might be slower, because of, but not exclusively due to, the high costs associated with upfront investments.

As emerged during analysis of the case studies, the adoption of digital tools and techniques such as BIM, digital twin and/or other cloud platforms for data sharing also entails higher transparency throughout the construction phases, contributing to better monitoring and control. In particular, deviations from the initial planning could be easily detected and investigated so as to understand the causes and to present possible solutions. This way, major errors in evaluating time and costs for the realization of specific construction projects could be avoided, resulting in a higher levels of trust among all of the parties involved.

3.2 Regulation and standardization

As previously stated, governments tend to be perceived as a fundamental players in the digitalisation process of the construction sector. The analysis of case studies reinforces this view, showing that most successful projects are highly dependent on a positive relationship between the public and the private sector.

In general terms, interviewees think that when drawing up new regulations, governments should set the goal they would like to achieve while allowing companies to decide on the best strategy to reach the objective. There is consensus that regulations need to be steady, clear and consistent to reduce uncertainty and stimulate digital transformation. Some companies advocate for "soft changes" in

regulations to give everybody the opportunity to adapt to such a revolutionary change. In order for this to happen, closer collaboration between the private and the public sector should be encouraged, for instance through the creation of ad-hoc working groups aimed at discussing specific aspects of digitalisation – i.e. the UK "Construction 2025" is a partnership between the UK Government and the industry the aim of which is to enhance the competitiveness of the construction industry. This partnership is led by the Construction Leadership Council which gathers representatives from different organisations across the sector to ensure that the joint commitments made by the Government and the industry are met.

Most of interviewees are convinced that the public sector should be in charge of bringing the players from the construction sector all along the value chain, to the table and coordinating their work with the aim of facilitating the discussion among different parties so as to favour the adoption of commonly-agreed solutions in support of digital transformation. This way, regulators can be constantly updated regarding the status and evolution of the discussion on digitalisation and they can legislate in accordance with the needs of the sector.

Business-to-government data sharing (also known as B2G) is another very important aspect to the collaboration with the public sector. As affirmed in the communication "Towards a Common European Data Space" public sector bodies produce and collect huge quantities of data, which could be further exploited for the development of innovative digital services and better policy making. In this sense, the EU Commission is currently reviewing Directive 2003/98/EC on the re-use of public sector information (see box below)[11].

The objectives of the review are the following:

- *reduce market entry barriers, in particular for small and medium-sized enterprises, by lowering charges for the re-use of public sector information*
- *increase the availability of data by bringing new types of public and publicly funded data into the scope of the Directive: (i) data held by public undertakings in the utilities and transport sectors, and (ii) research data*
- *minimise the risk of excessive first-mover advantage, which benefits large companies and thereby limits the number of potential re-users of the data in question, by requiring a more transparent process for the establishment of public-private arrangements*
- *increase business opportunities by encouraging the publication of dynamic data and the uptake of application programming interfaces (APIs).*

Source: European Commission, COM (2018) 232 Final, Towards a Common European Data Space (2018)

Moreover, in order to facilitate the use of public data across borders, the European Commission has launched the European Open Data Portal that contains data from EU institution and other EU bodies.

Particular attention should be devoted to the theme of standardization. As previously anticipated, a majority of the companies interviewed support the adoption of commonly agreed standards for on-site

[11] COM (2018) 232 Final, *Towards a Common European Data Space*

data exchange as they consider it a precondition for digitalisation to occur. Currently, the ISO/TC 127/SC 3 is revising the ISO/TS 15143-3:2016, which "specifies the communication schema designed to provide mobile machinery status data from a telematics provider's server to third-party client applications via the Internet – the data is collected from a mobile machine using telematics data-logging equipment and stored on a telematics provider's server"[12] (see box below).

ISO/TS15143-3: Earth-moving machinery and mobile road construction machinery – worksite data exchange

The ISO/TS15143-3 defines a communication schema able to provide information about on-site vehicles and their telematics data via a set of web services from the equipment manufacturer or a third party telematics provider to the equipment owner.

More operationally, this standard defines the communication records to be used when requesting data from the provider's server in which the data is stored and the responses from the server that must contain the specified data to conduct the analysis on the machine's health and performance, enabling the equipment owner to manage a mixed fleet. This communication schema concerns earth-moving machinery and mobile road construction machinery.

Twenty standardized data elements have been made available from OEMs and third party telematics providers; the API features with which EMM machines were equipped was prepared by OEMs to provide machine data using a predefined data format: the data elements include, among others, machine location, hours, fuel usage, peak travel speeds, PTO hours, caution codes, operating hours, idle hours, fuel remaining, DEF remaining, engine running, digital input states, engine load factor, load counts and payload counts. The related Technical Specification has been reviewed and commented and the preliminary publication date is foreseen at the beginning of the 4th quarter of 2018.

Another important initiative is being carried out by the CEN Technical Committee 442 on Building Information Modelling, which was launched in 2015. The Committee is in charge of developing "a structured set of standards, specifications and reports which specify methodologies to define, describe, exchange, monitor, record and securely handle asset data, semantics and processes with links to geospatial and other external data […] The aim is to help the construction sector to be more efficient and sustainable by enabling a smooth and comprehensive information exchange and sharing between partners in the value chain."[13] The work is still in progress.

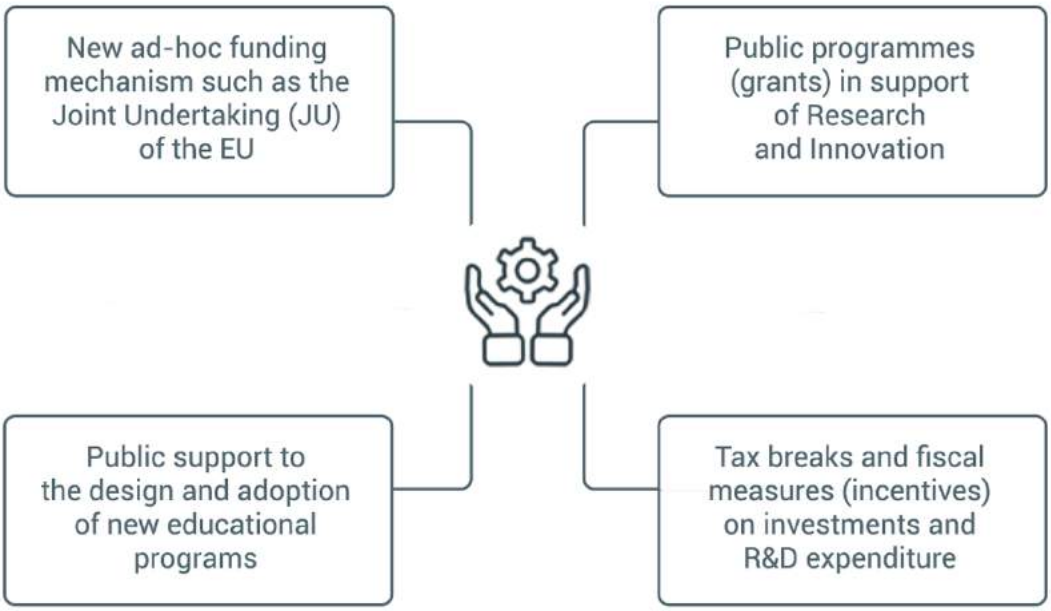
[12] For further information, see the following link: **https://www.iso.org/standard/67556.html**

[13] Jrc Technical Reports, Building Information Modelling (BIM) standardization, for detailed information see: **http://publications.jrc.ec.europa.eu/repository/bitstream/JRC109656/jrc109656_bim.standardization.pdf**

3.3 Public Funding

Based on the analysis of interviews and case studies, we can state that public funding proves to be an excellent instrument to support digital transformation of the sector. However, companies see the need to harmonize programmes and policies at EU level through a closer collaboration between the construction industry and public authorities to channel the resources towards common objectives and maximize the impact of public support.

Several forms of public support have been quoted as being useful for digitalisation:



Source: ID Consulting and S.I.RI.O.

- Public programmes (grants) in support of Research and Innovation (such as Horizon 2020, COSME, ESIF);
- Tax breaks and other fiscal measures (incentives) on investments and R&D expenditure (i.e. the Italian *Piano Nazionale Industria 4.0*, the French *Nouvelle France Industrielle* and the Dutch *Smart Industry*)
- New industry-driven funding schemes in support of the digitalisation of the construction sectors at EU level – i.e. PPPs and/or Joint Undertakings[14] – that foresee a joint effort from both the public and the private sector can be a powerful tool in accelerating digital transformation and harmonizing initiatives carried on at national level. This would partially relieve the construction industry from the

[14] Article 187 of the Treaty on the Functioning of the European Union (TFEU) specifies that the EU may set up joint undertakings (JUs) or any other structure necessary for the efficient execution of EU research, technological development and demonstration programmes. Article 187 TFEU has been used under the EU's seventh framework programme for research and technological development (FP7) and the Horizon 2020 research framework programmes to set up, in particular, public-private partnership bodies in order to integrate industrial research in specific areas. The members of these JUs are typically the European Union (represented by the European Commission) and, industry-led association(s), as well as other partners. JUs adopt their own research agenda and award funding mainly on the basis of open calls for proposals (source: **https://eur-lex.europa.eu/summary/glossary/joint_undertaking.html**).

investment costs they could incur, freeing resources for SMEs to accelerate their digital transformation.

- New forms of public support for the design and adoption of new educational programs at all levels in support of the digitalisation of the construction sector (for further information, see chapter 5). In order to be effective, such programmes should see the collaboration between national authorities (i.e. Ministry of Education), academia and the construction industry.

4. Skills and competences

4. Skills and competences

There is a consensus among the companies interviewed that the digitalisation wave will gradually alter the labour market in the sector in the coming years. Interviewees identified the followings as the major trends regarding skills and competences.

4.1 General Trends

New skills and competences

It's unanimously recognized that skills will gradually change as a consequence of digital transformation. What is less clear, at the moment, is the pace at which this change will occur. Companies in every segment of the construction sector will need to acquire digital skills (see image below) because of the growing need of collecting, analysing and managing data. As driver-assistance systems and self-driving machines are becoming the norm, future workers will have to be equipped with the skills to use tablets and other smart devices that will make the use of machines and the monitoring of processes and operations on the jobsite much easier. Data such as the topography of the worksite, soil volumes, fleet location, status of the project, tasks assigned will be easily accessible on smart devices, thus facilitating the exchange of information and communication on the jobsite.

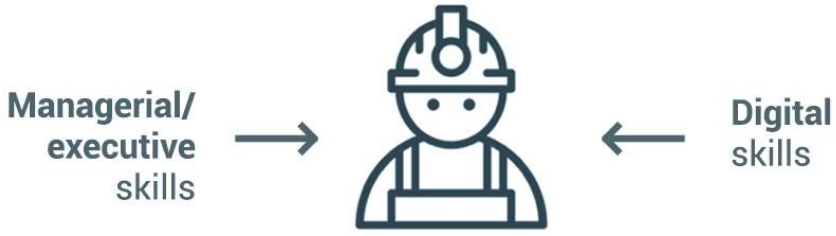
ICT Safety	Personal protection Data protection Digital Identity protection Security measures Safe and sustainable use
Digital communication and collaboration	Communicate in digital environments Share resources throught online tools Link with others and collaborate through digital tools Interact with and participate in communities and networks Cross-cultural awareness
Digital data processing	Identify, locate, retrieve, store, organise and analyse digital information, judging its relevance and purpose
Problem-solving with digital tools	Identify digital needs and resources Make informed decisions on most appropriate digital tools according to the purpose or need Solve conceptual problems throught digital means Creatively use technologies Solve technical problems Update own and other's competence
Digital content creation	Create and edit new content (from word processing to images and video) Integrate and re-elaborate previous knowledge and content Produce creative expressions Media outputs and programming Deal with and apply intellectual property rights and licenses

Source: ESCO EU skills/competences, qualifications and occupations website: ***https://ec.europa.eu/esco/portal/skill***

Considering the need to internalize advanced ICT skills, analysis of the interviews shows there's still disagreement on the subject. If there are some players interested in developing a knowledge base on ICT, many others prefer to stick to their business (i.e. building machines) and to strike deals and partnerships with IT players as the cost of opening a new IT department would be too high. Some players, however, strategically decided to acquire other ICT start-ups so as to have access to the competences they were looking for (see Hitachi case study in chapter 7).

▸ *Rethinking education for future organisations*

Digital transformation is not limited to the adoption of digital equipment and innovative software. Digitalisation means also rethinking (if not reinventing[15]) organisations and their business models. As a result, not only technical skills will be affected by the digitalisation process but also managerial ones. Resulting, in the need to rethink education and training so as to serve the objective of equipping current and future employees with the necessary digital and technical skills while also addressing the need to create a new class of executives capable of leading organisations in the new digital scenario (i.e. innovation managers).



Source: ID Consulting and S.I.RI.O.

Awareness of the potential of digital technologies – in particular, data analytics – and their impact on organizations and on construction processes is indeed a prerequisite to digital transformation. As stated by one of the companies interviewed, "before having data scientists in the company you must make people aware of the potential of data".

Management roles will be increasingly distributed on the jobsite because of digital transformation. For example, thanks to automation and remote control, the operator who was heretofore sitting in the truck and moving around the construction site will now have to sit in an office, coordinating three machines at once – that's why managerial and planning skills to coordinate a complex site will play a key role. Managers are increasingly expected to proactively act and to coordinate independent teams (for further info, see the box Squadification in chapter 3).

[15] The term is taken from to the book *Reinventing Organisations*, written by Frederic Laloux.

The gap between high-level and low-level jobs will increase

A high number of interviewees claim that one of the "undesired" effects of digitalisation is the gradual disappearance of highly technical jobs. As an example, resources such as skilled wheel loader or excavator operators run the risk of being gradually excluded from their role because of the introduction of autonomous driving. Thanks to the adoption of driving assistance systems, skills that were once required to operate a machine will not be useful anymore as anybody will be able to drive a digitized machine. On the one hand, such jobs will be replaced by higher level positions (i.e. software developers, app programmers) where employees will be responsible for working out innovative solutions for the connected jobsite. On the other hand, because of the simplification of some tasks, there will be an increase in the number of lower skilled operators on-site.

Digitalisation can overcome the generation and gender problem

From the interviews it emerges that the construction sector suffers from a "generational issue". Older workers, who have developed a strong expertise and knowledge, represent the majority of the construction workforce (in the US the average age of construction workers has increased by seven years between 1985 and 2014 and the trend is similar in EU countries as stated in the European Construction Sector Observatory reports). However, they tend to be less open to the adoption of digital technologies. While the average age of construction workers has been constantly increasing and in many cases retirement age is approaching, it is not been coupled with an increased presence of younger generations. Young people still consider the construction sector as "dirty, dangerous and demeaning". This is also one of the reasons why the number of women in the sector tends to be much lower than their male counterparts.

However, digitalisation is reversing this trend as technology may well represent an important element of attractiveness (both for women and men). Everybody agrees that digital natives are particularly open to the adoption of new technologies and that they can play an important role in the years to come in fostering digitalisation inside the construction sector. Nevertheless, historical know-how will still play a fundamental role in maintaining high competitiveness in the sector – especially among capital-intensive companies – therefore it will have to be reconciled with the paradigm of the new digital society.

Companies will foster collaboration with academia

A significant number of companies – especially among the bigger ones – are already used to providing customers with training on the use of new technologies and solutions onsite. However, the need for new skills and competences also entails a closer collaboration with the educational system at all levels. If collaboration with universities on R&I is fundamental, we can also say that companies in the construction sector see the need to find new forms of collaboration with VET schools and universities for the creation of new educational programs aimed at training future employees. Some companies already cooperate with business and technical schools for the organisation of common seminars and events to stimulate awareness around new opportunities and this form of collaboration is expected to grow in coming years. We shouldn't forget that schools and universities can play a very important role in attracting new talents in the construction sector thereby tackling one of the major barriers to the digitalisation process.

5. A comparative analysis with other sectors

5. A comparative analysis with other sectors

5.1 A comparative analysis with Agriculture

Agriculture is by far the sector that could be seen as a reference when thinking about the future evolution of digitalisation in the construction sector. This is also true given that some OEMs provide equipment to both sectors. Therefore, the dynamics of digital transformation in agriculture should be closely monitored as it could serve as an example to the construction sector when facing future challenges of digitalisation.

5.1.1 Business models

Business case

As in the construction sector, finding the business case was (and still is) the major problem in shifting towards a digital model. Some recent studies claim that digital farming – considered as "the evolution in agriculture and agricultural engineering from Precision Farming to connected, knowledge-based farm production systems"[16] – might boost income of about 20% while favouring a reduction in herbicide and fuel consumption of 10%.[17]

Calculating the return on investment in agriculture might be perceived as an easier task when compared to the construction sector. Processes in agriculture appear far more repetitive especially given that we are talking about fixed plots of land while construction sites (i.e. civil engineering, road building) are subject to constant changes. However, this view could be misleading because agriculture is subject to other sector-related problems, firstly high levels of uncertainty and volatility related to external factors (i.e. weather conditions). Elements such as weather, soil composition, presence of insects, air humidity and irrigation needs have all to be considered when designing holistic models for revenue generation (see paragraph the value of data).

It is also true that in agriculture the cost of digital equipment is significant limiting the pace of digitalisation in the sector. In conclusion, even in the case of investment there tends to be more similarities than differences between the two sectors.

Servitization and collaboration

The agriculture sector can be taken as an example of the servitization trend as it is increasingly becoming the norm due to digitalisation. Thanks to the pervasive use of IoT technology and of an increased connectivity in the fields, OEMs can provide extra-services to farms such as predictive maintenance but also more complex services such as forecasting and advising on the agriculture cycle with the aim of improving efficiency and boosting productivity. In order for that to happen, new forms of collaboration with external players (in particular the IT industry) are emerging. However, digitalisation also entails an increase in competition: in order to maintain competitiveness, they will need to go beyond the traditional offer by providing customers with comprehensive solutions that foresee the

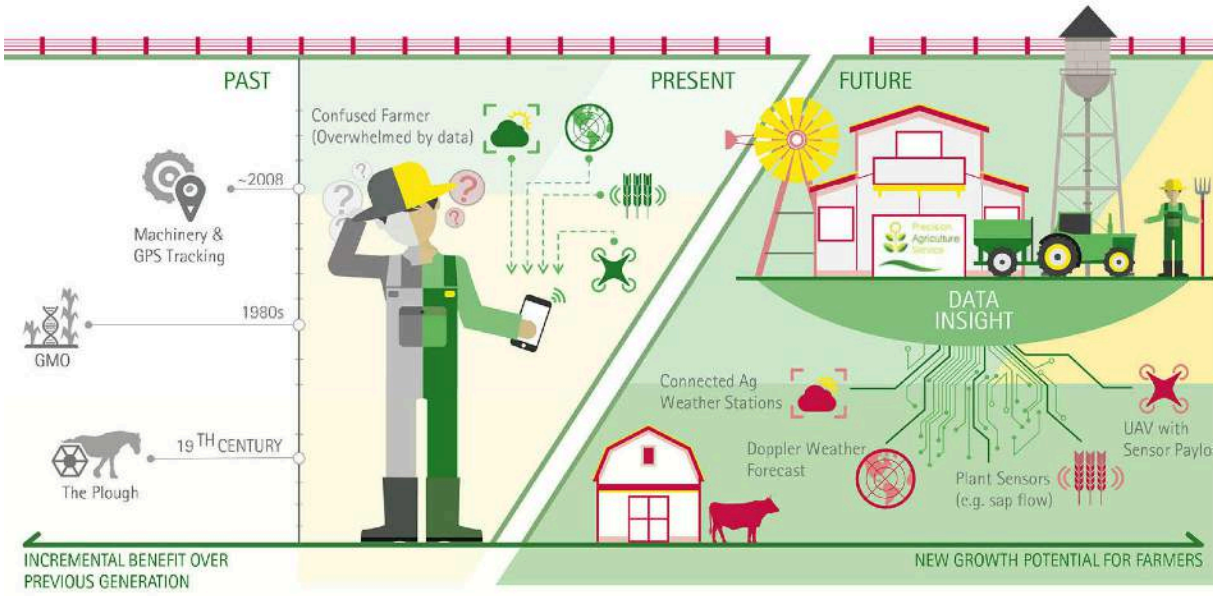
[16] "Digital Farming: what does it really mean?", European Agricultural Machinery, February 2017. Available: http://cema-agri.org/sites/default/files/CEMA_Digital%20Farming%20-%20Agriculture%204.0_%2013%2002%202017.pdf

[17] JRC, "Industry 4.0 in agriculture: Focus on IoT aspects", Digital Transformation Monitor, July 2017.

management of the entire ecosystem thereby following an outcome-based approach. From that point of view, similar examples exist in the construction sector – as demonstrated by the case studies of Hitachi and Komatsu (see chapter 7).

The value of data

In agriculture, enhancement in productivity and efficiency is closely linked to the capacity to collect, analyse and exchange data. For the sector to exploit the full benefits of digitalisation, connectivity problems in rural areas needs to be solved. In general, data can be used for a variety of purposes such as predictive maintenance, fleet management, food traceability, improved communication and more. Moreover, data could be also used in order to provide complex services (i.e. consulting services such as "farm management advising") as already mentioned in the previous paragraph. The growing awareness around the business importance of data is leading to the emergence of proprietary data platforms that can sometimes be perceived as a threat by farmers (particularly SMEs), especially if they hold a dominant market position creating strong barriers to entry. Therefore, the creation of a more advanced architecture – such as a publicly supported open platform – where everybody can connect though APIs is considered a necessary step in avoiding potential risks.



*Source : Accenture (**https://www.accenture.com/us-en/insight-accenture-digital-agriculture-solutions**)*

As in the construction sector, the agriculture sector also sees an overlap of interests between the various actors in accessing data from field processes. However, some steps have been taken to solve potential frictions. In particular – as already mentioned in Chapter 2 – Copa and Cogeca, CEMA, Fertilizers Europe, CEETTAR, CEJA, ECPA, EFFAB, FEFAC, ESA adopted the EU Code of Conduct on Agricultural Data Sharing on April 23rd, 2018. The Code of Conduct contains a series of non-binding principles on the rights and obligations of accessing, (re)using and sharing data that are reflected in contractual agreements among the parties.

5.1.2 Skills and Competences

As in the construction sector, the ageing workforce is a key issue to be tackled in agriculture. According to some estimates, 56% of employees are over 55, (year 2013)[18] so the number of skilled operators capable of facing the challenges of the digital revolution are limited. On the one hand, increasing automation allows for a reduction of physical workload and greater safety; on the other, it means that "old" jobs will gradually disappear leaving room for specialized ones that require the use of digital skills – such as the use of tablets and other smart devices to operate agriculture equipment. In addition, future employees will have to be equipped with planning and managerial skills in order to take decisions with the support of data-driven tools such as Artificial Intelligence and Decision Support Systems. In this perspective, there's a need to increase investment in training – together with the public sector – and reskilling to favour the adoption of digital technologies. Initiatives aimed at increasing awareness regarding the potential advantages of using digital technologies in farming are of paramount importance in boosting digital farming.

5.1.3 Relationship with Public Authorities

The digitalisation process in Europe is significantly influenced by the EU Common Agricultural Policy (CAP), that according to some recent declarations is expected to allocate increasing resources to the digitalisation of the sector in the years to come[19] helping the transition to Digital Farming, especially among SMEs.

OEMs in agriculture recognized that the end-user – the farmer – must be able to choose machinery from different manufacturers. This in turn entails the need to improve interoperability though the definition of clear standards on communication to favour the exchange of data among players all along the value chain – which is a prerequisite to reaping the benefits of data. Beside the standard ISO 11783-1:2017 that "specifies a serial data network for control and communications in forestry or agricultural tractors and mounted, semi-mounted, towed or self-propelled implements"[20], AgGateay and AEF "have joined forces to make the standard for data exchange future-proof and adapt it to the needs of Digital Farming."[21]

[18] European Commission, "Industry 4.0 in agriculture: Focus on IoT aspects", July 2017. Available: **https://ec.europa.eu/growth/tools-databases/dem/monitor/sites/default/files/DTM_Agriculture%204.0%20IoT%20v1.pdf**

[19] European Commission Press Release, EU budget: the Common Agricultural Policy beyond 2020, available: **http://europa.eu/rapid/press-release_IP-18-3985_en.htm**

[20] International Organization for Standardisation, available: **https://www.iso.org/standard/57556.html**

[21] European Agricultural Machinery, "Connected Agricultural Machines in Digital Farming", February 2017. Available: **http://cema-agri.org/sites/default/files/CEMA%20PT3%20-%202017%2001%2020%20-%20AEF-AgGateway%20collaboration%20web.pdf**

5.2 A comparative analysis with Commercial and Public Use Vehicle

Manufacturers of vehicles for transporting people and goods, and in particular, road transport, are greatly affected by digitalisation and in broader terms by the effect of the Fourth Industrial Revolution – or Industry 4.0.

Although many similarities exist between the automotive and the construction industry, digitalisation takes different forms. In the automotive sector digitalisation concerns a much wider spectrum of applications and innovations, mainly because its products – in particular, cars – are consumer goods. We can identify three main differentiating features between the two sectors:

- The widespread ownership of the vehicle
- The relevance of data interchange among vehicles and with the surrounding infrastructures
- The relevance of the issue of CO2 emission reduction[22]

As a result, investments destined for digitalisation were focused on the one hand on product development and on improving production processes while on the other on the adoption of new business models that foresee the provision of additional services such as predictive maintenance, fleet management, and so on.

However, for the sake of the research we prefer to limit the field of research to vehicles that are conceived for the realization of a specific outcome – i.e. commercial and public use vehicles such as school buses, public buses, ambulances, car sharing vehicles – because in this case the differences with respect to the construction sector tend to be less evident.

5.2.1 Business models

Business case

The reduction of CO2 emissions and the optimization of transport routes in a world where mobility of goods and people as well as remote connection are growing rapidly, requires deep rethinking on the need for new business models. Ownership of the vehicle becomes less and less necessary, and the focus is concentrated on the need to move people or goods from point A to point B in the shortest time and at the lowest possible cost. The development of intermodal, collective, individual and freight transport highlights the need for more customized vehicles to carry out specific actions with the aim of reaching specific outcomes, increasing similarities with the construction sector – in particular, the shift towards an outcome-based model.

In order to meet the new market requirements, OEMs are gradually transforming their model so as to provide an integrated service to follow all stages of transport and fleet management. In this case, shifting towards a digital model represents a great opportunity.

The return on investment in this sector is directly linked to competitiveness and to the provision of full services or data monitoring of the vehicles' operational life. At the same time, manufactures need to

[22] Directive 2007/46 / EC and related documents - https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=LEGISSUM%3An26100

ensure the presence of auxiliary systems to operators such as driver-assistance systems or security management tools.

Servitization and collaboration

Even if for the time being, in the automotive sector the individual ownership model of the vehicle is still the norm, new approaches are emerging. These are gradually shifting towards sharing economy or pay per use models. It must be underlined that also minor changes in the business model aimed at satisfying more digital-oriented customers need to be accompanied by deep reflection about the sustainability of the new model, especially in terms of competitiveness.

In urban areas, sharing solutions are heading towards electric and/or hybrid models that favour a decrease in CO2 emissions both for private and commercial transport. As a result of this change, it emerges the need of improving collaboration with the actors all along the value chain to improve customer satisfaction, vehicle management, pay per use billing, safety features, management of recharging stations and so on. At present, different kinds of companies and new operating players are entering the market, resulting in a growing need for standards, agreements on data sharing, commonly agreed roaming fees as well as the adoption of basic common interfaces. As in the construction industry, the focus on reducing CO2 emissions and the shift towards an outcome-based model – thanks to the adoption and use of digital technologies – is gradually becoming the rule when determining the investment decisions that the automotive industry will have to take in the coming years.

The value of data

The evolution of production systems and the growing human-machine interaction was responsible for an increase in awareness regarding the value of data in the automotive sector. The availability of digital technologies leads to the introduction of innovative solutions for a more integrated management of services, from production to management to after-sale monitoring. At product level, in the automotive sector services such as driver-assistance and self-driving systems, V2V and V2I communication, electrification, emission reduction, passive and active safety, technologies such as IoT, Cloud, Robotics, Data Exchange Technologies, Mobile Communication and Multimedia Interface proved to be very important. In particular, the use of Data Analytics, IoT and Cloud technologies offer the possibility to develop customized, long life and fleet management services. In more general terms, operational data around vehicle location and real-time communication exceeded the value of the vehicle's technical features. While the latter are subject to long-term update procedures, the former allows manufacturers and intermediate operators to continuously redesign new forms of services and business models that meet the needs of customers. The digitalisation of customer experience in marketing & sales and aftersales coupled with the higher interaction between customer and OEM contributes to the overall potential of the company. Moreover, also professionalizing internal processes such as R&D, manufacturing and supply, and support functions by digitalising them plays a very important role in increasing profitability – that according to some estimates might reach 36.3% per cent.[23]

[23] Andreas Gissler, Clmens Oertel, Christine Knackfuss, Franziska Kupferschmidt, "Are you ready for pole position?", 2016, Accenture Strategy.

5.2.2 Skills and Competences

Being part of the wider automotive industry, the problems related to skills and competences were partially tackled some years ago. At the same time, the development of multimedia interfaces and integration with mobile devices has attracted new generations of workers and new talents. In general, highly digitalised and agile organizations require deep reflection on the organisation of human resources from design to manufacturing, to customer service, maintenance and so on, which in turn leads to higher level of inclusion of younger and digital native personnel in the staff. In addition, in recent years, various forms of cooperation with high schools and universities offering high-level specialization courses and the possibility to upgrade the skills of older workers have been established.

5.2.3 Relationship with Public Authorities

Because of the size and the type of sector, the relationship with the public authorities is a fundamental element for its evolution and digital transformation in the future. On the standardisation side, specific standards exist to increase communication between vehicles and the surrounding infrastructure such as the IEEE std 802.11 p and IEEE Std 1609. However, for other advanced application such as collision avoidance or autonomous driving more time is required to insure wider adoption.

One interesting and pioneering example of digitalisation in the EU is represented by the Connected and Automated Mobility policy that sees the collaboration of Member States, Industry and the European Commission in determining "the vision for the connected and automated mobility in the Digital Single Market". In fact, "29 European countries are committed to the development of large-scale testing sites of connected and automated driving on European motorways in the form of cross-border corridors"[24]. Public authorities will also play an important role in setting rules on CO2 emissions, causing a significant impact on the sector. At the moment Regulation (EU) 2018/956 of the European Parliament and of the Council of 28 June 2018 on the monitoring and reporting of CO2 emissions from fuel and fuel consumption of new heavy-duty vehicles, strengthening the role of data management, from the vehicle approval.[25] The document contains specifications on the way in which data should be managed for the control of emissions, in relation to the vehicle approval standard. This highlights the importance of the role of data in the vehicle's operational life to ensure an appropriate and sustainable use in terms of safety and environmental sustainability. Public transportation is also strongly influenced by the public sector, in particular the development of Smart Cities will have a revolutionary impact on the pace at which digitalisation will occur, thus opening the way for new opportunities to improve efficiency and quality as well as customer experience and loyalty.

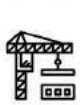
[24] For further info, see: **https://ec.europa.eu/digital-single-market/en/cross-border-corridors-connected-and-automated-mobility-cam**

[25] For further info see: **https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32018R0956**



	Construction	Agriculture	Commercial and Public Use Vehicles
Business models			
Importance of Business Case	As the cost of digital transformation is high, the identification of a clear business case is of paramount importance. However, calculating a clear ROI might be difficult due to the complexity of construction processes.	Digital transformation is linked to the identification of a clear business case. Even though agriculture processes tend to be more repetitive than in the construction sectors, the number of variables to consider (i.e. humidity, soil moisture, weather conditions) makes a clear calculation of ROI more complicated.	ROI is directly linked to the provision of integrated services to accompany all stages of transport and fleet, upon which depend the competitiveness of the companies.
Servitization	The servitization trend is growing in the sector thanks to the increasing use of digital technologies, in particular, the extensive use of IoT and data analytics.	OEMs in the agriculture sector are increasingly shifting towards the servitization model thanks to the introduction of technologies such as IoT, drones and data analytics.	There is a gradual shift towards sharing economy and pay per use models. Servitization is becoming a trend: a differentiated level of intermediate services covers a large part of the market.
Importance of an outcome-based approach	The servitization approach means that companies are increasingly providing outcome-based solutions, following a "selling 'holes' rather than drills" approach.	Thanks to the widespread adoption of digital technologies in the sector, new outcome-based solutions are emerging aimed at improving efficiency and productivity.	The new business models that are emerging in the sector are gradually shifting towards an outcome based model.
Awareness on the value of data	Awareness on the value of data is emerging, especially among large companies.	Awareness of the business importance of data is growing in the sector and has been recognised for some years.	The sector is increasingly working on solutions aimed at extracting value from data. Data analytics, IoT and cloud allow the development of customized long life fleet management services.

Emergence of data sharing models	Some B2B models (i.e. Banking Model) are emerging to facilitate data sharing between companies in the construction sector.	Aside from B2B models, the agriculture sector has adopted a common non-binding model on data sharing (Code of Conduct on data sharing in agriculture).	There are both B2B models related to fleet management and optimization of resources and B2C models oriented to the sharing economy and integration with the services of smart cities.
Skills and competences			
Workforce composition	An ageing workforce represents a problem for the sector, especially if coupled with the lack of new resources due to the low attractiveness of the sector. This trend could be reversed thanks to digitalisation.	56% of employees are over 55 in the agriculture sector, representing the majority of the workforce, limiting the number of skilled operators able to face the changes brought about by digitalisation.	The attractiveness of the sector, even if reduced compared to the past, still remains high. The development of multimedia interfaces and integration with mobile devices have attracted younger generations of workers and digital talents.
Trainings on new skills	The construction sector needs training in new skills, both at a managerial and a technical level.	Due to the introduction of digital technologies and subsequent changes, future employees will have to be equipped with planning and managerial skills in order to take decisions based on the support of data-driven tools.	In recent years the sector has established various forms of collaboration with high schools and universities providing highly specialized courses and upgrading the skills of the existing workforce.
The impact of automation	Automation is on the one hand responsible for workload reduction but on the other it will cause a change in workforce composition. New jobs will emerge in the sector such as data scientist, software developer and remote-control operator.	Because of automation, "old" jobs will gradually disappear leaving room for specialized ones that require the use of digital skills – such as the use of tablets and other smart devices to operate agriculture equipment.	Automation has reduced the presence of traditional figures that have gradually been replaced by a higher number of employees in charge of management of services throughout the operating life of the vehicle.



Relationship with public authorities			
Standardization	The discussion on standards, interoperability and communication for data exchange is still on-going. Agreement has been found on the standard ISO/ TS15143-3 (Earth-moving machinery and mobile road construction machinery – worksite data exchange)	At the moment, the ISO 11783-1:2017 for communication and data exchange among tractors. AgGateay and AEF are working on standards for data exchange to respond to the needs of Digital Farming.	Specific standards exist to increase communication between vehicles and the surrounding environment, such as the IEEE std 802.11 and IEEE std 1609. In addition, work is still in progress concerning advanced application such as collision avoidance or autonomous driving.

6. Roadmap to digital transformation

6. Roadmap to digital transformation

In order to effectively innovate a business model, companies should focus on how the use of new technologies can be interfaced with emerging market needs. However, translating the potential of digital technologies into an operational strategy for digital transformation is not an easy task. We should be mindful of the one feature that has been identified as a common denominator of digitalisation: data.

As stated in the first chapter, digitalisation means accessing information to gain insights and to leverage the "power of information" derived from the collection, analysis and management of data to provide new solutions with a higher value added. Therefore, the ability to manage data represents the most important element in transforming business models.

The research shows that digitalisation, if properly managed, can play a major role in increasing a company's competitiveness and it could even change the positioning along the value chain in relation to customer needs. That said, we could now attempt to establish a roadmap for business transformation, as described below.

This chapter stems from the analysis of part of the existing literature on the "digital transformation" subject and crossed with the interviews. In particular, four major sources were considered when drafting the following paragraphs:

- "The Digital Enterprise Moving from experimentation to transformation", World Economic Forum – in collaboration with Bain & Company, (2018);
- "The Transformative Business Model", Harvard Business Review, Kavadias, S. Ladas, K., Loch, C., (2016);
- "Digital Transformation Now!", Schallmo, Daniel R. A., Williams, Christopher A., (2018).
- "Reinvent Your Business Model" Mark W. Johnson, (2018),

6.1 Identifying the elements for change

In general, the following enabling factors need to be in place in order to shift to a digital model.

Awareness on the value of data

In order for digital transition to be effective, it is necessary to start from setting up a strategy that clearly states how data can become a source of value for a company. Particular emphasis should first be put on the objectives that the company wants to achieve through data analysis and then introduce analytics to create high added value products and services – and not the other way around.

Adoption of technologies for data collection and analysis

Internet of Things, drones, BIM and other tools for data collection on operations and processes are fundamental. These must be coupled with data analytics and AI to extract the most relevant information from the ecosystem and transform it into knowledge, with the objective of supporting companies in introducing innovative solutions aimed at improving processes and operations.

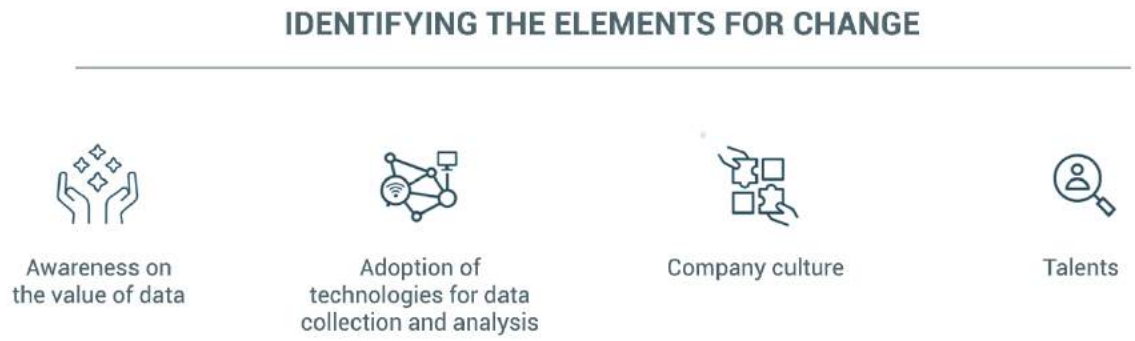
Company culture

Culture is a leadership issue and, as such, organisations need to be prepared for such a disruptive change in the business model. Company culture plays a significant role in favouring the transition to an

innovative model where collaboration between colleagues, with customers and partners is perceived as an undisputed value and where innovative models of HR management become the norm.

Talents

The power of digital transformation is highly dependent on the people that work inside organisations, who can make a real difference. On the one hand, companies must make every effort to attract/develop and retain new talent that are fit for the digital age; on the other, they must engage them in the transformation process from the initial phases, avoiding leaving anybody behind. Introducing a coaching culture which develops independent continuous learners, and self-responsible collaborative individuals, as well as Leader Coaches trained to support and sustain constant change and evolution will be fundamental to the success of digitalisation.



Source: ID Consulting and S.I.RI.O.

6.2 Setting up the strategy

Digital transformation is far from an easy process. Most digital strategies are not successful for various reasons – most of all because the impact of such a disruptive phenomenon is not fully understood. Every company that decides to embark on digital transformation needs to take several elements into account, as described below.

▸ *Analysing the ecosystem*

Market dynamics

Companies need to consider the evolution of the market and, in particular, understand as early as possible which direction the construction sector is taking by analysing the behaviour of the entire value chain and by taking inspiration from examples offered by other sectors. The key element to consider is what will be the nature or the dynamics of the industry in 5, 10, 20 years.

Role of the Public Sector

Being one of the industry's main clients, the public sector plays a crucial role in the construction industry. That is why companies need to be clearly informed about the evolution of policy making in the sector. Being involved in the regulation process from the early phases can guarantee them a higher return from the digitalisation efforts.

Self-assessment

Before embarking in digital transformation, companies in the construction sector need to analyse and classify internal processes, the current level of data processed in relation to customers and the ways in which they generate value by activating resources, people, processes, partners and their financial capacity. Therefore the data that must be taken into consideration to conduct such classification relates to the current business model structure of the company, the value-creation chain and its segments, the actors involved and the relationship between them, the customer segments and the current and future requirements of the market.

Source: ID Consulting and S.I.RI.O.

Prepare for change

Define the Value proposition

Companies need to define the job-to-be-done, intended as the "product/service that does a job that customers need and that can be supplied to them at a price they can afford"[26], this job serves the progress that the client wants to achieve in a given circumstance. Companies should also define a vision for the market segment they would like to cover and that makes them unique vis-à-vis their competitors. Thanks to the current revolution and the data available, companies can acquire a lot of information from the customer and perform the necessary analyses on it. By doing so, companies clearly state their vision, which is their distinctive element of competitiveness. This could entail also rethinking the type of offer they are delivering to the market thus opening the way for the provision of new products or services.

Define technology solutions

The next phase corresponds to the analysis and evaluation of state-of-the-art technological solutions available on the market to be adopted or implemented by means of research and development. This phase should start with a mapping of best practices, including cross-sectorial ones, and of the useful tools or technologies available, proceeding then with an analysis of their accessibility in terms of the

[26] Mark W. Johnson, "Reinvent your business model", Harvard Business Review Press, July 10, 2018

resources and skills needed. Going into more detail, the definition of technology solutions includes, for example, the definition of data platforms, the understanding of protocols, identification of suppliers, etc.

Rethinking the organizational structures

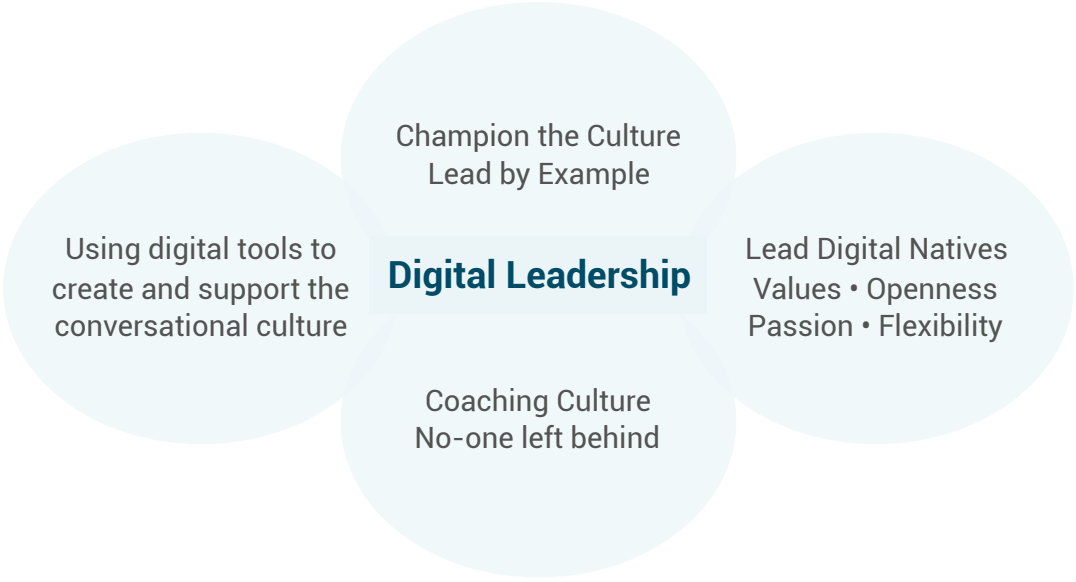
Digital change requires a deep rethinking of the organization as the interaction with customers and the IT sector will continue to increase, new forms of collaboration will emerge, hierarchies might gradually disappear, leaving multidisciplinary teams in charge of developing more customized solutions that better serve the needs of the market and of end-users. Digitalisation is a synonym of higher participation (thanks to the use of digital technologies), which in turn means gradually shifting focus from producers to consumers, who will increasingly influence production processes. By rethinking corporate governance, companies should empower the teams in charge of developing such customized solutions and provide a favourable ecosystem for innovation to thrive.

Identify the financial strategy

Digital transformation means deeply thinking about how companies want to manage the transition to a new business model from a financial point of view. In that regard, the cost model should clearly state that the adoption of digital technologies represents value for the organization. If so, every effort should be made in order to guarantee adequate funding to digital transformation by tapping into a wide array of financial sources – such as venture capital, banking funds, public grants. When the risk of shifting towards a new business model is perceived as too risky for the running business, the process of digital transformation can be transferred into a separate entity (parallel startup) with the right allocation of financial resources.

Look for employee buy-in

Leaders need to showcase new ways of working while tapping into the company's resources and overcoming the potential fears that may rise while moving to a digital scenario. New organizational forms (i.e. squads) and new collaboration tools need to be adopted so as to favour communication inside the company at every level. Buy in will require a new breed of leader coaches who embrace culture change and lead from the front by example. Leaders who recognise the value of self-responsible individuals and are willing to support their people in and beyond the introduction of new technologies and digital realities.



Source: ID Consulting and S.I.RI.O.

Engagement with Public Sector

Business leaders need to build and maintain a continuous relationship with the public sector with the aim of influencing the regulatory framework. This means that companies should be more involved in policy making in the initial phases by establishing a steady dialogue with public authorities, by collaborating with academia and governments for the creation of new training paths for the "employees of the future" and for the reskilling of existing ones and by stimulating public support in terms of funding.

Community & Stakeholder Engagement

The role of the consumer will change as a result of emerging technologies, meaning that consumers will have a higher stake in determining the characteristics of the products/services they want to be provided with. This will lead to a revolutionary change in the relationship between the citizens/ consumers and the industrial sector. The interests of the industrial sector will increasingly converge with those of consumers, requiring a repositioning of enterprises in society with the aim of creating shared value that will benefit the society as a whole.

Source: ID Consulting and S.I.RI.O.

▸ *Design the new business model*

Digital transformation requires the definition of a new business model whose solidity depends on the following aspects:

Customization of products and services

Digital technologies favour a bidirectional exchange of data among parties, thus contributing to higher customization thanks to improved communications. The customer must be engaged and win every day, if not, companies will lose them. Therefore, products need to be increasingly personalized and tailored to customer needs, opening the way for the development of new services in addition to their traditional offer (servitization).

Outcome-based revenue model

The servitization trend implies the need to rethink the revenue model so as to understand where the added value lies in providing the solution to the customer. As data technologies mean higher transparency which in turn benefits the final user, an increase in competition is expected to happen in

the coming years. The outcome-based approach is highly consumer-oriented, so strong effort should be made to reduce waste and to focus on high added value solutions for the market.

Use of Data-Platform

The introduction of data platforms is an essential element of the new business model for the following reasons:

- they contribute to better communication among partners, subcontractors and end-users thus improving management of processes and operations on-site through enhanced forms of collaboration;
- they allow for a greater exchange of information thereby reducing costs thanks to an increased asset sharing and greater transparency that favours a better allocation of risk all along the value chain
- they allow better forms of monitoring of construction processes and resilience;
- they contribute to the creation of new streams of revenue directly linked to the value of data per se, that can be leveraged both by the actors all along the value chain and by other sectors/industries to design new products and services.

Agile Organization

This requires a capacity to identify new ways of working so as to become agile. Companies need to rethink the appropriate operating model, the nature and extension of collaboration with external partners based on the required competences, the governance strategy (i.e. parallel start-up), key performance indicators, recruitment strategy and HR organisation (i.e. decentralised teams) to optimize the full network inside and outside organisations. Companies need to react quickly to market decisions by adopting a multi-step iterative approach that allows them to fully understand the advantages that digitalisation will bring to their own businesses before facing the challenges of such a change.

Sustainability

Environmental and social sustainability are gradually becoming an important element of competitiveness. The market is increasingly keen on rewarding companies that take good care of the ecosystem where they live and prosper, thus accommodating the end-users' growing attention to sustainability and ethical values. As a result, this convergence of interests between enterprises and end-users/consumers causes a repositioning of industry within society that favours the creation of shared values, thus benefitting society as a whole while simultaneously stimulating economic growth.

The table below serves the purpose of creating a parallel between the information of chapter 6 and the case studies described in chapter 7.

	Setting up the strategy	Case studies
Analysing the ecosystem		
Market dynamics	Companies need to consider the evolution of the market and to understand which direction the construction sector is taking by analysing the behaviour of the entire value chain.	**The Connected Jobsite** Following market trends an ICT/IoT solution (Solution Linkage) was developed that works closely with the customer to improve safety, increase productivity and reduce life-cycle cost.
Role of the public sector	Companies need to take a close look at the policies and funding programmes of national, regional and EU authorities that favour digitalization in order to increase the opportunity of experimenting with innovative solutions.	**Digital Road Building in Practice** Having a clear interest in reducing the overall expenditure of repairing previously built infrastructure, the German Ministry of Economics and Energy saw a benefit in funding this project through the "Autonomik für Industrie 4.0" program framework.
Self-assessment	Before embarking in digital transformation, companies in the construction sector need to analyse and classify internal processes, the current level of data processed in relation to customers and the ways in which they generate value by activating resources, people, processes, partners and their financial capacity.	**Electric Site** The companies involved in this project decided to look at the quarry operations from another angle and to consider the dynamics of the entire ecosystem to improve overall efficiency in the quarry site. This was the precondition for the introduction of new and innovative solutions.
Prepare for change		
Define the Value proposition	Companies need to define the job-to-be-done, intended as a product and/or service that does a job customers need and that can be supplied to them at a price they can afford.	**A Brand-Independent Collaboration Software** Normally, contractors have a mixed fleet of machines with machine control from different brands, as a result it gets difficult to gather uniform data from the machines for future use. INFRAKIT B.V.'s tool was conceived as brand-independent to facilitate easier data exchange.
Define technology solutions	Companies need to analyse and compare the best technological solutions (i.e. IoT technology, protocols, suppliers) in accordance to their needs and objectives.	**Telematics in Mixed Fleets** In order to keep track of the use and maintenance of machines and to avoid unauthorized machine use, OHL chose to implement Trackunit's telematics system in its mixed fleet.

Rethinking the organizational structures	Digital change requires a deep rethinking of how organizations are structured. Given that the interaction with customers and the IT sector will continue to increase, new forms of collaboration will emerge, hierarchies may gradually disappear, leaving multidisciplinary teams in charge of developing more customized solutions that better serve the needs of the market and of end-users.	**Electric Site** There are several actors involved in this project: Volvo CE is coordinating the project and is in charge of developing the machines and systems, Skanska Sweden is providing logistical solutions, application relevance and job site knowledge, the Swedish Energy Agency is providing financial help and the universities are carrying out research.
Identify the financial strategy	Digital transformation means deeply thinking about how companies want to manage the transition to a new business model from a financial point of view. In that regard, the cost model should clearly state that the adoption of digital technologies represents value for the organization.	**Bricklaying in the Digital Age** When a building boom in Western Australia coincided with a shortage of bricklayers, driving the cost of laying a brick up, the solution developed by the founders of FBR became a viable and necessary innovation. Because of the rapid advancement of digital technologies, cost trajectories were in favour of the adoption of the new bricklaying robot Hadrian X.
Look for employee buy-in	Digitalisation entails new ways of working and collaborating internally. To overcome resistance to digital technologies and to build a company culture able to respond in an agile way to digital transformation, communication and collaboration and readiness should be constantly enhanced.	**Managing Complexity in the Construction Site** Baumaster's innovative documentation, communication and collaboration platform connects engineers, interface builders, architects and executing companies, thus constituting a network and improving communication between them.
Engagement with Public Sector	Companies should establish a steady dialogue with public authorities to bring their expertise on potential solutions to economic and societal challenges to policy makers as well as to stimulate forms of public support for digitalization both on the regulatory and financial levels.	**Smart Construction** As part of the "i-Construction" framework initiative, the Japanese government, set ambitious objectives to digitalize construction processes in order to improve productivity and face up to a severe workforce shortage. Komatsu took up the challenge and delivered new solutions to optimize the entire construction process though the extensive use of ICT technologies.
Community & Stakeholder Engagement	Therefore, construction companies should find ways to reposition themselves in the community with the aim of creating shared value that will benefit society as a whole.	**3D Modelling and BIM Applied** In Dundee, BAM employed around a dozen people from the area and averaged 56% of local labour on site, bringing economic benefits to the region.

Design the new business model		
Customization of products and services	Products need to be increasingly personalized and tailored to customer needs, opening the way for the development of new solutions.	**Electric Site** The close collaboration between Volvo and Skanska for the duration of the project lead to the development of new concept machines, work methods and site management for the quarry industry.
Outcome-based revenue model	The servitization trend implies the need to rethink the revenue model in order to understand where the added value lies in providing the solution to the customer. The outcome-based approach is highly consumer-oriented, so a concerted effort should be made to reduce waste and to focus on high added value solutions for the market.	**The Connected Jobsite** Hitachi developed "Solution Linkage", an ICT/IoT solution that allows for three major outcomes: improve safety, increase productivity and reduce life-cycle costs. By equipping machines with highly developed IT solutions, Hitachi is providing higher value to the product it delivers to its customer (machines) by working closely with the customer and its partners.
Use of Data-Platform	The use of data platforms is an essential element of the new business model for several reasons: they facilitate communication and exchange of information among stakeholders, they allow better forms of monitoring of construction processes and resilience and they serve as a way of creating new streams of revenue linked to the value of data.	**Optimizing Construction Processes** The software solution developed by Volz Consulting GmbH allows site managers, installers, mixer operators, truck drivers and forwarding companies to exchange data in real-time, thus ensuring a more efficient and stress-free construction process. The use of such software creates awareness among all systems operators regarding the progress of the project and allows for timely responses to problems.
Agile Organization	Today, new challenges require an agile approach. This means rethinking the operating model and establishing collaboration with external actors, according to the outcome the company wants to achieve and to respond efficiently and in a sophisticated manner to these challenges.	**Digital Road Building in Practice** The Smartsite project saw collaboration between a wide partnership: Ammann Group (Ammann Verdichtung GmbH) as construction equipment manufacturer, Topcon Deutschland GmbH (digital provider) and ceapoint aec technologies GmbH (software provider), as well as construction companies such as Deutsche Asphalt GmbH and Zueblin/ Strabag AG. These companies pooled their efforts in order to address the issue of avoiding defects on road asphalt compaction.

Sustainability	The market is increasingly keen on rewarding companies that take good care of the ecosystem where they live and prosper, thus accommodating the end-users' growing attention to sustainability and ethical values, that are becoming an important element of competitiveness.	**Electric Site** The project was designed to achieve the same output as Skanska's usual equipment but, crucially, with up to 95% lower carbon emissions and up to 25% lower total cost of operations. In brief, it proved to be highly sustainable both from an environmental as well from an economic point of view.

7. Case Studies

7.1 3D Modelling and BIM Applied

The Challenge

In 2015 BAM was engaged by Dundee City Council, in Scotland, to build the V&A Dundee museum of design, designed by Japanese architect Kengo Kuma. The project represents a vital reconnection between the city and its historic waterfront along the River Tay and it had to deliver the architect's vision of a "living room for the city": a welcoming space that everyone can visit, enjoy and use as a space for socialising. V&A Dundee opened its doors to the public for the first time on Saturday 15 September 2018.

The building of the V&A Dundee museum was a challenge: the museum is composed of two separate three-storey buildings, joined at roof level. The outer walls take their inspiration from the surrounding Scottish cliffs. Curving concrete walls (there are no straight external walls) hold 2,500 pre-cast rough stone panels, weighing up to 3000 kg each and spanning up to 4m wide. There are 21 separate wall sections. V&A Dundee is an impressive 8,000m² building, with 1,650m² of gallery space. The sinuous curves are actually formed from a series of concrete panels – every one of them with a different profile – inset with lighter coloured pre-cast concrete slabs. Creating and installing these shapes presented some significant challenges.

The solution

In order to realize this milestone project, several techniques were applied. In the first place, BAM created a cofferdam: a temporary structure that retains water and soil, allowing the enclosed area to be pumped out and excavated dry. Six hundred and twenty temporary piles were inserted into the riverbed, which allowed the temporary reclaiming of a section of the river to construct the foundation section of the building. The cofferdam also provided a platform to construct the concrete frame at an angle, to create the distinctive overhang and attach the perimeter precast planes on the side of the building. Once the works were complete, the cofferdam was removed and the river was re-flooded up to the building.

This milestone project was only possible thanks to the use of digital 3D modelling. BIM technology proved to be fundamental for the construction of V&A Museum and it benefitted the project with regards to time and the amount of work the engineers have had to do on-site. Using traditional engineering methods would have taken much longer and it would have cost more.

Key Success Factors

- **A pioneer work.** V&A Dundee is an impressive feat of engineering. Nothing like this has ever been constructed in Scotland before. It is an incredibly organic shape and form that makes it very attractive.
- **Significant reduction in time thanks to the use of BIM.** Due to the complexity of the project, there were a lot of different details (i.e. ceilings, partition, door details). Having access to such a huge amount of information on the iPad saves a lot of time in terms of going to the office, printing drawings and taking them on site.
- **Local economic benefits.** At the start of the project, BAM organised a successful 'Meet the buyer' day with Dundee Council to recruit a local workforce. The team succeeded in its target of employing around a dozen people from the Dundee area new into the industry and has averaged 56% local labour on site.

Barriers to innovation

- **Complexity.** There were two main obstacles: on the one hand the installation of the cofferdam to allow the building of one section of the museum in the river and on the other the external concrete reinforced walls due to their complex shape both curving in the horizontal and vertical as they travel up the building.
- **Curved walls.** Every wall of the V&A Museum of Design Dundee is curved: sometimes both horizontally and vertically. This double curvature created a problem. When a straight-walled building is constructed, there could be a difference of up to ten millimetres between plans and the final result. For the V&A Dundee project, that gap could be no more than three millimetres. Therefore, the accuracy of the project needed to be millimetre perfect.

Lessons learned

- **The use of 3D modelling is the key of success.** Being able to access the model on site, via tablets, helped to ensure that each element of the building frame was set out to millimetre-perfect tolerances. It was possible to go into the model using Point Cloud Survey, take the information

required, download it onto the instrument on-site and then that would allow it to be to set it out with confidence that it was right.

- **Company's vision of digital technologies.** The vision of BAM is "Making before we make it", which means constructing the digital twin of the asset before it's built and testing out all the scenarios of the project on that digital asset before reaching site where problems are much more expensive to resolve. As 84% of organizations that attempt digital transformation fail, BAM has the clear objective to be in the 16% that succeeds.
- **Collaboration with expert partners.** For the building of the V&A Museum BAM relied on some important partners such as structural steel contractor Severfield to manage the complex construction sequence, with its interdependencies between the steel and concrete elements. Moreover, it has an Enterprise Business Agreement with Autodesk to support the delivery of the digital transformation – for instance through the access to consultants who work with BAM to develop solutions to delivering projects. The network also helps users to operate technologies and with any problems they might have.

7.2 Optimizing Construction Processes

The Challenge

In the construction industry as in other industries, time is money, so builders are constantly seeking to streamline and modernize their operations. Communication issues are frequent, and stakeholders often witness many problems while interacting and checking the construction site current status. The sector needs really lean and easy-to-use systems, that can assist the operators in checking the situation, in making fast decisions and in helping them during risky operations. Furthermore, the increasing digitization in road construction brings with it changes and adjustments. Construction companies are increasingly confronted with topics such as "Industry 4.0", "Lean Management" or "Building Information Modelling (BIM)".

The solution

The software solution "BauProzessOptimierung" (BPO), developed by Volz Consulting GmbH, brings construction companies a lot closer to practical applications. With BPO, all of the processes in civil engineering and road construction become simpler, faster and more transparent, from project planning

and resource coordination, to construction, to evaluation and mobile work time recording. Site managers, installers, mixer masters, truck drivers and forwarding companies are networked together to ensure a more efficient and stress-free process as well as improvement in overall quality.

Documentation is greatly simplified: during the construction phase, the installers can keep track of how many trucks and how much materials is on the road and can change the planning dynamically; the system also elaborates the data created by the sensors (which refers to both the position of machines and their operations) and instantly produces related documentation concerning what is happening.

BPO is also provided with a Building Information Modelling (BIM) interface: all data is causally linked so that text messages, photos, delivery note data as well as data related to installation and production can be attached to the respective construction sections or GPS positions. For example, it is possible to follow exactly where the delivery notes were installed and which mixing plant delivered material for which phase of construction, even long after completion of the project.

Key Success Factors

- **User-friendliness.** With BPO, all processes in civil engineering and road construction, from project planning and resource coordination to construction, evaluation and mobile work time recording, become simpler, faster and more transparent.
- **Data management tool.** Site managers, installers, mixer operators, truck drivers and forwarding companies can exchange data in real-time thereby ensuring a more efficient and stress-free process. The site manager does not have to produce different planning for various operators; with simple and clear user interfaces, all system operators can respond quickly to problems and support the construction with additional functions such as the integrated messaging centre or material consumption control.
- **Digitization of paper documents**. Owners and contractors have more control over the construction process, as BPO allows them greater ease in handling digital information derived from all of the different processes.

Barriers to innovation

- **Conservative behaviour.** Such disruptive technology needs some time to be implemented by construction companies due to a possible resistance to change.
- **Data sharing issues.** In the construction sector data sharing is a very sensitive issue and collaboration could be really difficult if not properly organized through clear and transparent contractual agreements and with a clear vision around the advantages of sharing information among the partners.
- **Resistance from the workforce.** Before fully implementing such disruptive technology, people have to be convinced about the advantages that this technology can bring to the overall company.

Lessons learned

- **Finding the business case.** Volz Consulting GmbH focused on a clear necessity in the road construction sector in order to provide a much needed solution, which proved to be very successful.
- **SMEs can be powerful at providing flexible solutions**. Born as a consulting company, Volz Consulting GmbH evolved rapidly into an IT company thanks to the development of a new software

tool (BPO) in so doing demonstrating a high level of flexibility in turning digital when opportunities arose in the market.

- **Data sharing is a key element of competitiveness.** The success of the company shows that an ecosystem approach to the problem, through the use of digital solutions, improves efficiency in the road construction sector.
- **Digital skills are a key element.** Systems such as BPO are deeply dependent on the skills of operators, who are increasingly required to master digital skills in order to successfully accomplish their tasks.

7.3 Smart Construction

The Challenge

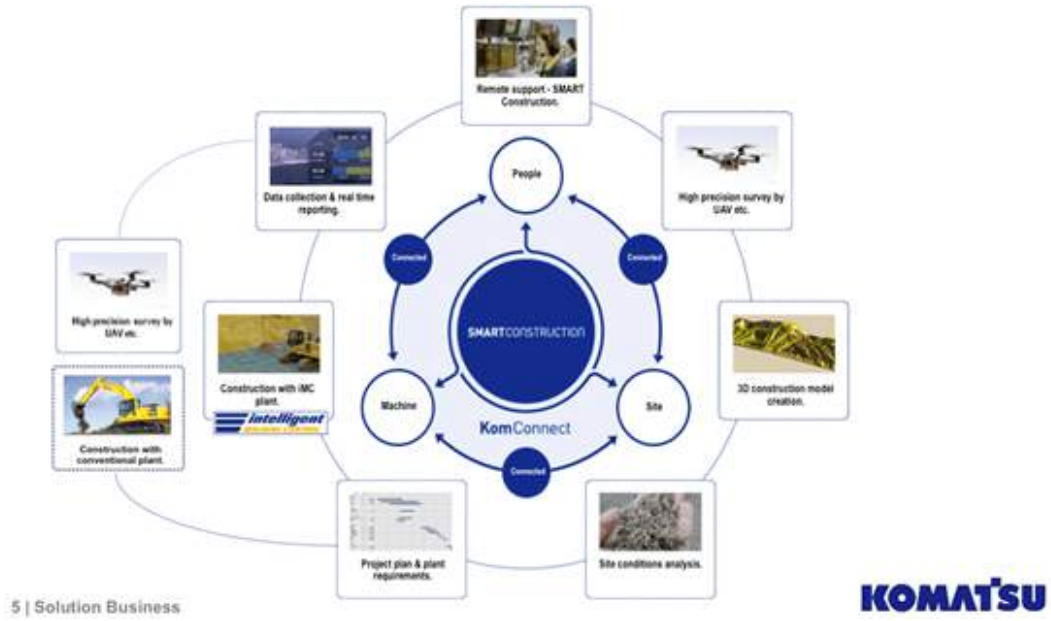
Japan is currently facing a severe workforce shortage in the construction industry, which is predicted to decline by 1.3 million - it is anticipated that about 40% of skilled workers will retire by 2025. Since 2016, the Ministry of Land, Infrastructure, and Transport has been promoting "i-Construction," aiming to improve productivity per skilled worker by 50% using ICT technology. Additionally, (Road) construction job sites are complex throughout the complete process, from study, to engineering, to tender to execution. Quality failure costs (human related) are reported to represent up to 20% of a projects original contract value.

Faced with this scenario, Komatsu started to explore new ways to optimize the entire construction process though the extensive use of ICT technologies throughout the construction industry.

The solution

In order to solve the problem, Komatsu launched a new concept called Smart Construction in 2015. Smart Construction is a service that incorporates the worksite into the IoT (Internet of Things), organically connecting everything present on the site, and enabling 3D "visualisation".

The main objective of Smart Construction is to connect all construction site information in order to improve overall construction processes and to provide integrated products, services and support solutions across all phases of a project. A wide array of services are included, such as: the use of drones to perform high-precision surveys and to transform information taken from a camera into 3D data through continuous reporting, calculation of precise construction areas, using the difference between the initial survey data and the 3D design data, automatic calculation of embankment and excavation soil volumes, observation of changing worksite topography in real time and monitoring of the fleet through automatic acquisition of information. All collected data is transferred to a unique platform (Smart Construction Cloud) that connects all of the operations on-site,opening the way for further analysis. Construction site data is developed through Artificial Intelligence analysis of equipment, vehicle and worker movements captured with on-site video camera with the objective of improving overall efficiency. In addition, 3D design data can be transferred from the Smart Construction Cloud to iMC construction machinery. Even if there are unexpected design changes, instant update is possible by registering the latest data and transferring it to the iMC construction machinery.



Source: Komatsu

Key Success Factors

- **User-friendliness.** The use of a single software rather than several proves to be very attractive to end users, who can easily learn how to adopt the new innovations on the construction site.
- **A servitization approach.** Beside providing customers with highly digitised construction equipment, Komatsu also provides solutions to issues related to following the construction process, management and on-site daily data collection.

- **Productivity**. One of the benefits of Smart Construction is a marked improvement in productivity. For example, in conventional surveying, thousands of terrain points are measured in a week. With drones millions of terrain points are measured in 15 minutes.
- **Higher precision.** Another advantage is that the 3D survey data obtained from the drones is more precise in terms of terrain measurement, with accuracy that has improved from units of several meters down to just a few centimetres.
- **Improved functionalities.** New functions have been added to assist the operation of construction machinery on the worksite. For example, the digging depth of a iMC hydraulic excavator or iMC bulldozer can be automatically controlled to a precision of ±30 mm based on the combined technology of integrated GNSS with stroke sensing cylinders eliminating unnecessary work from over-digging.
- **Improved Safety.** Normally, an assistant would be required to stand near the construction machine to direct the operator —a dangerous task in itself. But semi-automatic control eliminates the need for an assistant, significantly improving safety. Another benefit is that operations that once required a certain degree of expertise can now be carried out by less or unskilled operators.

Barriers to innovation

- **Data storage and protection.** The adoption of digital technologies entails a huge increase in the amount of data generated onsite. Therefore, data storage capacity (i.e. servers) needs to be significantly improved to assist in the collection of data that could be (re)used for further analysis. Attention should also be placed on increasing security of data storage against cyber-attacks.
- **Standards.** Lack of harmonized standards across Europe may slow down the spread of the Smart Construction solutions.
- **Different markets.** Solutions that might work well in one market (i.e. Japan) cannot easily be replicated in Europe, as the environment is more fragmented and the need to comply with the different market conditions can reduce the commercial activity. Currently ongoing tests are taking place in different countries in Europe to determine what can be rolled out.

Lessons learned

- **Data sharing and ecosystem approach**. Thanks to the use of a common cloud platform everything involved in the construction process such as people, equipment, topsoil and earth are connected and can be visualized in real time; moreover, big data coming from construction processes can be analysed to achieve optimization throughout the construction phases. In summary, the platform acts like the "brain" of Smart Construction, it brings together all of the information related to a project, connecting people and machines while providing them with up-to-date information from a variety of sources on or off site, available at any time on a variety of devices
- **Collaboration with partners and customers is essential to reaping the benefits of data sharing.** On one hand, collaboration with the IT companies is necessary to bring digital solutions onsite. On the other, to reap the full benefit of the new technologies, customers must be involved from the very beginning as improvements can only be reached if an ecosystem approach foresees the use of ICT across entire construction sites rather than construction equipment only.

- **Open innovation approach.** As Komatsu cannot process all of the data on its own, the platform has been designed to be open for anyone to join. Construction site data includes not only data from Komatsu equipment. Using the information there will be various business opportunities, which may lead other businesses to join the process.
- **An innovative corporate philosophy.** Komatsu believes that construction machinery manufacturers must not only provide worksites with construction machinery equipped with the latest technology but they must also provide the systems to make maximum use of this construction machinery.

7.4 Managing Complexity in the Construction Site

The Challenge

Due to the ever-increasing complexity of tasks, project managers are now faced with the challenge of keeping everything in overview. Many meetings regarding Coordination and documentation tasks require resources that are often not available for large or multiple projects, which can lead to overloading. The pressure to succeed is increasing where projects no longer have much leeway. Subcontractors are under enormous pressure to sell their services in tenders. A lot of deviations in the project can later cost a lot in terms of money and nerves until the project is finally completed. In summary, various systems and processes currently make efficient project management difficult, given that request processes, planning processes, task processes, control processes and communication processes do not run together. For instance, according to Baumaster internal estimates, 15% of working hours are used daily to search for and drop off expended documents, 20% of working hours are spent in meetings and 20% of working hours are lost resulting in higher costs.

Source: BauMaster

The solution

Baumaster has developed a documentation, communication and collaboration platform for the entire construction process. The construction process is documented from planning to completion. All participants should participate in this process and can network their service to ensure a smooth construction process. Baumaster is designed as a platform for the construction industry, over which meeting protocols of various kinds - such as acceptance reports and defect reports - as well as the entire documentation of the construction site should run. Baumaster can digitize protocols, photos, lists and status reports of the individual trades, thus creating a uniform solution for all of the companies involved in the construction business. Baumaster software places the engineering, interface builders, architects and executing companies on a new communicative level, constituting individual networks; in addition, the actors involved in the construction project can view and edit up-to-date to-do lists independently on their own devices by accessing the online platform (even without an Internet connection), in this way they can know the state of advancement of the project from anywhere and at any time and have planning, tasks, information and documents all stored in one place only. With Baumaster, the possibilities offered by digitisation are put to use with the requirement for fast, up to date and content-usable information and collaboration exchange.

Key Success Factors

- **Optimized information-flow between all partners.** Baumaster improves communication by sharing information amongst all of the contractors and partners, through a single platform. Having all of the information stored on a platform enables all of the partners to have efficient and structured project organizations reducing conflicts, discussion and uncertainties.
- **High quality from planning to execution.** Material and staff capacities can be scheduled on time and up-to-date to-do lists are managed by all of the actors involved. During the entire length of the project quality checks can be performed preventing potential errors. Keeping track of the tasks performed on-site and having all of the useful sources stored in one place means that nothing is overlooked or forgotten, enhancing the efficiency of the workflow and ensuring that deadlines are met in the predetermined time.
- **Cutting unnecessary costs.** Thanks to the Baumaster platform, there are significant time savings in logging and inspection; as well as prevention of defects through the constant defect management performed that results in a decrease in costs related to time spend. In addition to reducing time, the Baumaster platform allows more capacity for new and additional orders when projects are completed or scheduled without incurring any delay and deviation.
- **Improved quality of work.** Having access to a platform where all of the information regarding the project is stored and tasks are managed within independent networks, means that employees are always optimally informed and know what to do, this results in a significant reduction in errors and time spent, with the possibility of introducing other tasks to be performed in this "extra" time; through this, stress and pressure on site are reduced, allowing for a good working and communication climate.
- **The trust of the customer is strengthened.** Deploying such a platform at a project level leads to more transparency and safety, which also positively impacts the final customer who will be kept informed, in a timely manner by the site manager, the qualified experts and the surveyors on building progress, services and costs throughout the lifetime of the project.

  Baumaster platform allows all participating actors to respond to customer requests. This communication with the project partners protects the customer against unexpected surprises, wrong performance, defects or additional costs and their expectations are met.

Barriers to innovation

- **Sometimes digital basics are missing.** Mobile devices are not always managed and used on-site, making it difficult to access the platform.
- **Some companies lack a structured way of communicating.** Sometimes, the internal structure and the behaviour of organizations may represent a barrier to change, this being so additional effort should be put into demonstrating the advantages of the new solution and working out a strategy for redesigning a more effective internal communications process.
- **One size doesn't fit all.** There is not a starting solution, or a one size fits all solution to every company's needs. Businesses differ and may vary in their level of maturity with regards to digitalisation or they may approach digitalisation in diverse ways, given their specific characteristics and needs. This diverse view on digitalisation and varying level of maturity can represent an

obstacle to fully benefiting from what the Baumaster platform has to offer. Not only businesses differ but also people in both their use of digital devices (and consequently, the platform) and in their way of working.

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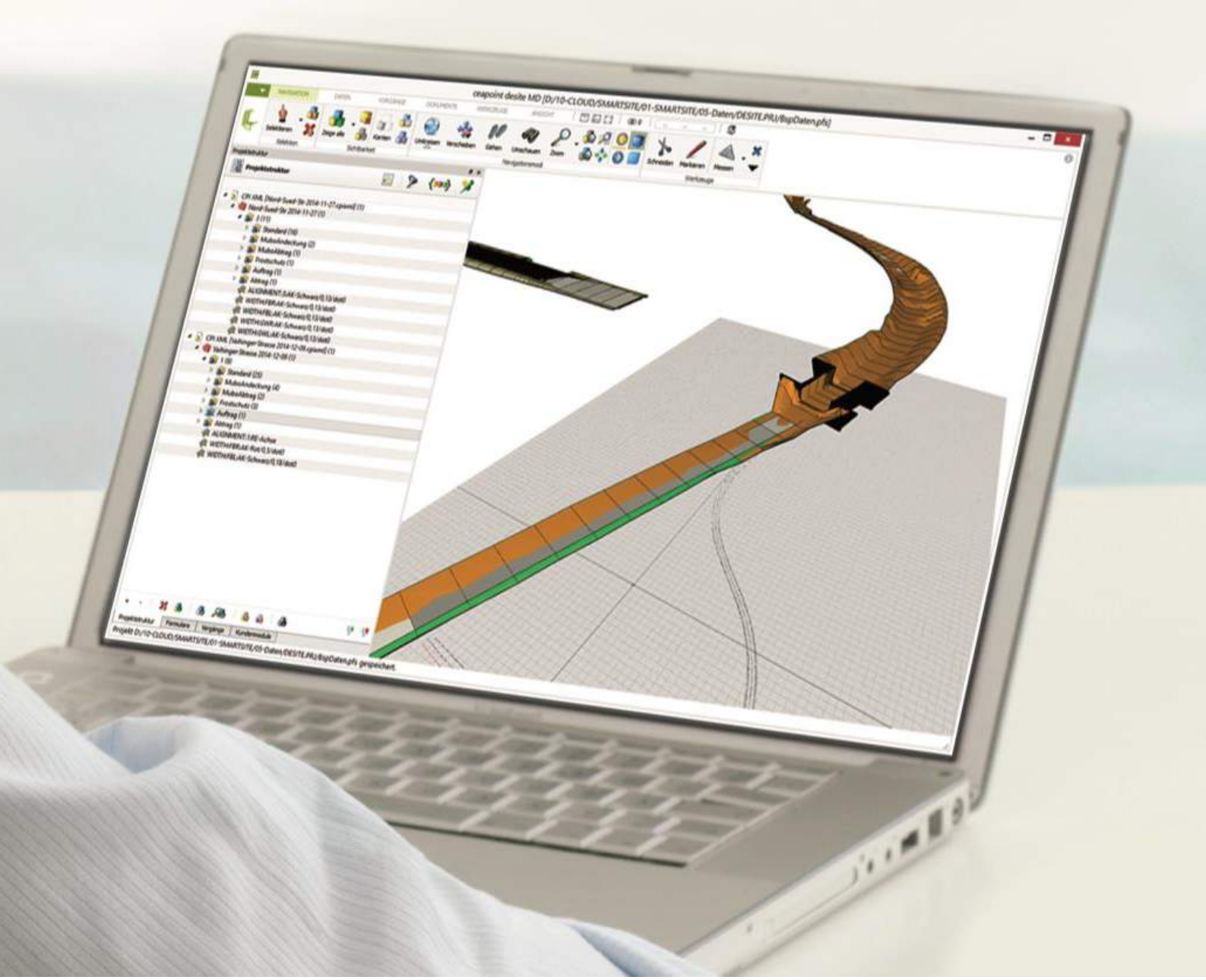
Lessons learned

- **Identification of a clear need.** Baumaster platform is the answer to a specific challenge in the construction sector: the difficulties in harmonizing information and communication amongst the partners involved in a project, which cause inefficiencies and delays
- **The ecosystem approach is a key element.** When all of the actors involved in a project are gathered together communicating in the same environment the picture is wider and everyone is aware of the project's progress and peculiarities. This results in overall efficiency and a reduction in time and errors.
- **Data sharing is a powerful tool.** The platform demonstrates that when the information flow is shared among the actors involved in the project the benefits for the whole project are significant.
- **Individualized training may be useful when the level of digitalisation is heterogeneous.** The company path shows that the level of approaching digitalisation differs in terms of businesses and people given that not everyone has the same focus. For this reason, ad hoc training is useful in assisting the actors to fully benefit from the deployment of the platform, this means beginning by figuring out where to start with companies.



7.5 Digital Road Building

The Challenge

"The European construction industry contributes nearly 10% to the EU-27-GDP but close to 90% of its projects suffer from budget overruns or delays. The main cause seems to be inadequate planning and management, specifically of capital-intensive infrastructure construction projects"[27]. Construction projects are characterised by high dynamicity and complexity, calling for coordination methods and strong collaboration all along the value chain so as not to incur project budget overruns and delays. If we consider asphalt road construction, the black-top assembly phase is influenced by several environmental, technical, social and managerial factors. "To get the right amount of asphalt on time and of the right quality (i.e., the right temperature) to the paver and "on the road" at minimum cost is quite a challenging task. The logistics chain includes asphalt batch plants, transportation facilities, pavers and compactors"[28]. Faults in the asphalt compaction phase may occur when operators are not adequately

[27] R. Kuenzel, et al., SmartSite: *Intelligent and autonomous environments, machinery, and processes to realize smart road construction projects*, Automation in Construction (2016), http://dx.doi.org/10.1016/j.autcon.2016.03.012

[28] ibid

supported by a system that assists them in the construction phase with real time information (such systems are mostly set up for monitoring performance after the construction phase). A fault in the asphalt compaction may be irreversible requiring the road to be milled off and rebuilt, leading to higher costs. Estimations show that "5% of the construction sum is spent on fixing quality defects"[29], that is why an adequate compaction of asphalt is necessary to provide high quality road construction and long lasting roads.

The solution

The SmartSite project addresses the issue of avoiding defects on road asphalt compaction. The project was funded by the German Federal Ministry of Economics and Energy in the framework of the "Autonomik für Industrie 4.0" program. The project kicked-off on November 1st 2013 and ended on October 31st 2016 with a total cost of 9.61 million euros (of which 6.65 million were allocated to the project costs and the remaining 2.96 million went for the material used). The SmartSite project combined a research and development phase with a "Final Demonstration" phase that took place on provincial road L1205 in the Swabian town of Filderstadt. The project brought, Ammann Group (Ammann Verdichtung GmbH) as construction equipment manufacturer, Topcon Deutschland GmbH (digital provider) and ceapoint aec technologies GmbH, a leading software provider for building process control solutions, together, as well as construction companies such as Deutsche Asphalt GmbH and Zueblin / Strabag AG.

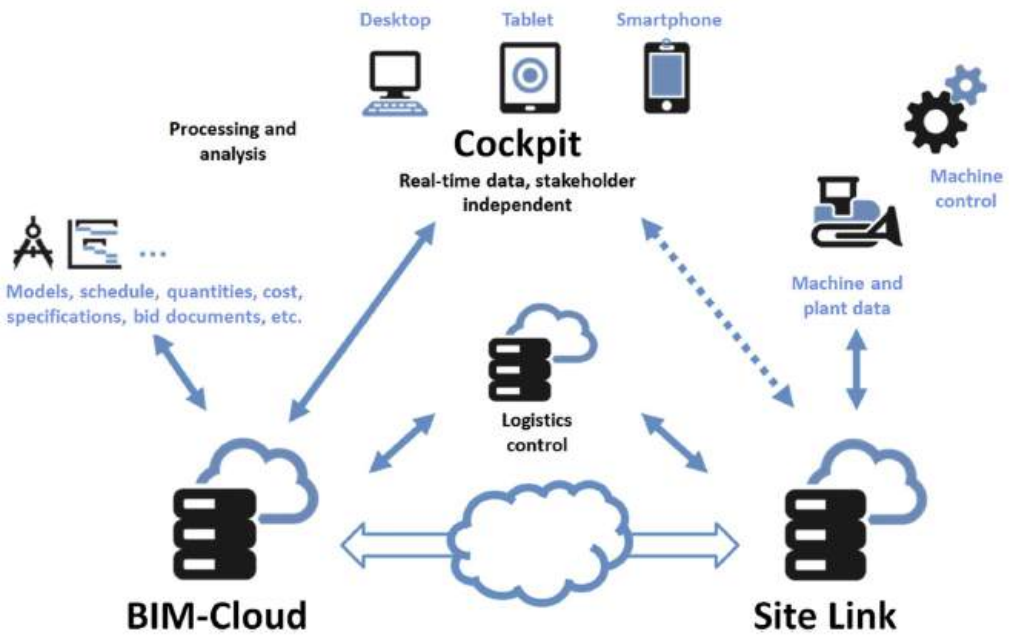
The SmartSite project supports human compactor operators with an assistance system capable of "generating driving instructions based on real-time sensory inputs and computational intelligence"[30].

This system addresses all steps in the logistics chain, from the asphalt batch to the end of the compaction phase by developing a multi-agent system made by "sensing and communication technologies that integrate real-time automated information exchange in the supply chain of road construction"[31]. In this way, data from individual machines, from the traffic, on the environment (data on weather conditions and forecast) and the construction processes are collected and transferred in real time between individual machines, between machines and the environment and between individual machines and construction processes. The SmartSite system integrates the BIM planning data with the digital, model-based construction process control and the actual machine data. Location-independent access for operators and machines is ensured by cloud based architectures as well as smart technologies (see image below). The control of the construction process execution is therefore performed using real time data derived from the construction site and supplied directly to the smartphones and smart tablets used on site. In this way, BIM applications are used more for the planning and pre-construction phase while the monitoring of the execution of construction processes is handled via mobile devices accessed by human actors on site.

[29] R. Kuenzel, et al., SmartSite: *Intelligent and autonomous environments, machinery, and processes to realize smart road construction projects*, Automation in Construction (2016), http://dx.doi.org/10.1016/j.autcon.2016.03.012

[30] ibid

[31] ibid



Source: "SmartSite: Intelligent and autonomous environments, machinery, and processes to realize smart road construction projects", Automation in Construction (2016), ***http://dx.doi.org/10.1016/j.autcon.2016.03.012***

Key Success Factors

Advantages compared to the current state of road construction practices were:

- **Improvement in the just-in-time arrival of materials.** Normally, asphalt mixing plants are not fully integrated in the road construction information systems, deliveries are not scheduled based on as-built information (schedules are often planned in advance with pre-set volumes per day) and the information on orders and bills of delivery between the delivery entity and the construction site is transferred using emails and fax. Thanks to the integration of asphalt plants and the live vehicle tracking, the pending arrival of trucks is transmitted to the plant in advance, reducing the time spent at the plant for each truck and allowing a more flexible adjustment of time deliveries.
- **Reduction in logistical downtime**. Coordination of logistics in road construction is often missing. Thanks to live vehicle tracking the asphalt deliveries are monitored in real time. Moreover, asphalt temperature can be monitored at any time thanks to data coming from temperature sensors in the truck or alternatively applied machine learning. The information coming from integrated asphalt plants and pavers allows a just-in-time scheduling of asphalt deliveries, which reduces the number of dump trucks that need to be available on site.
- **Improvement in the quality of road compaction.** Having integrated pavers with logistics components allows for the adjusting of the speed and the throughput of the paver while considering the material currently en route. Through the SmartSite system, pavers are also able to communicate with rollers, ensuring high quality and therefore longevity of the road asset. Overall, the SmartSite system assists human operators on site in the control of compactors in real-time. Thanks to compactor agents, which are a means to emulate the "behaviour of an immaculate human operator while utilizing the available sensor data and derived data in real time for additional

accuracy beyond human capabilities"[32] and additional sensory information, human operators are supported with an optimal assistance system. This system can generate instructions that, when followed by human compactor operators, lead to a higher quality in compaction results.

- **Comprehensive improvements of site communication, process documentation and process visualization.** Communication between machines and construction process control is facilitated by integrating the machine control with the BIM planning data, the individual machine data and the digital model-based construction process control, enriching existing tools for documentation and visualization.

Overall, the use of the SmartSite system showed a fundamental improvement, in the streamlining and automation of the construction processes as well as monitoring and documentation.

Barriers to innovation

- **Dependency on the availability of GPS tracking and a stable network connection.** Without an elevated GPS accuracy and a stable network connection for the transfer of data, machines are unable to determine each other's position, (the machine gets "blind" when GPS tracking or the network connection is missing); losses of network or GPS must then be compensated for by manual control of a human operator.
- **Human operators may not follow the instructions provided by the system.** If human operators are not properly instructed they may decide not to follow the paths calculated by the system and illustrated in the operator's cabin and this will negatively affect the construction processes and the performance of machines.

Lessons learned

- **Leverage digital technologies across the entire product lifecycle.** A fully digitalised construction process can optimise the operations and the final product quality overall. It might also reduce quality related faults and help to prevent the high costs of rectifying defects. The effectiveness of worksite and future maintenance can be enhanced substantially through a fully integrated digital communication and information programme. The data produced by the entire system from the meteorological sensors, tablets, smartphones, hauliers' trucks, paver and rollers can be analysed in real time and along the whole value chain. Massive integration of the system (that can also be seen as an Internet of Things model) results in better management of the whole construction system, improved accuracy in the construction operations and increased quality of the final result.
- **Consider the possible lack of skills.** The usage of such innovative technologies clearly implies users must be adequately prepared to handle it. That said, this is not always the case. The risk is that the workers or the contractors may eventually decide to take manual control of the operation if they perceive that the sensors do not respond to their wishes, resulting in a possible delay and a possible failure of the project.
- **Collaboration is key.** The collaboration between Ammann, Topcon, Zueblin, Drees & Sommer and CEA Point represents a common interest in cutting costs and reducing waste; the companies joined forces to create a system that would hopefully be appreciated by an evolving construction industry.

[32] R. Kuenzel, et al., SmartSite: *Intelligent and autonomous environments, machinery, and processes to realize smart road construction projects*, Automation in Construction (2016), http://dx.doi.org/10.1016/j.autcon.2016.03.012

The companies involved did not lose competitive advantage as a result of their collaboration, working as pioneers on new tech solutions.

- **Public funding is a trigger for the development of new solutions.** The role of the German Federal Ministry of Economics and Energy in stimulating innovation proved to be very important. Having a clear interest in reducing the overall expenditure for repairing previously built infrastructure, the public sector saw a clear benefit in funding this type of project.

7.6 Bricklaying in the Digital Age

The challenge

The construction industry is among the least digitised sectors in the world, and has had the lowest productivity gains of any industry over the past two decades. Furthermore, 90% of the world's infrastructure projects are either late or over-budget, and inadequate housing has become a global problem, with over a billion people currently living in slums. This number is expected to double over the next 15 years.

There is a clear need for a construction method that increases the speed, accuracy and safety of construction while reducing cost and waste to make construction a more affordable and sustainable industry. Higher demand for buildings directly linked to the rapidly rising population, coupled with the shortage of inputs for construction and technological advancement stimulated the research of a new solution for bricklaying.

Bricklaying has remained almost an unchanged process for thousands of years. In developing a solution for automated bricklaying, Fastbrick (FBR) needed to tackle the problem of how to take precision robotics outdoors for the first time. In doing this, it was necessary to solve the problem of stabilising a robot at the end of a long moving boom subject to environmental forces such as wind.

When a building boom in Western Australia converged with a shortage of bricklayers, driving the cost of laying a brick up, the solution developed by the founders of FBR became a viable and necessary innovation.

The solution

Hadrian X represents a turning point in global construction capabilities and practices. It is a unique construction robot mounted into a classic cab over engine truck to easily transport it to and from a location for on-site building. The robot component could also be mounted onto other bases such as tracks, barges, boats and cranes to bring this unique capability to a range of environments.

Using FBR's Dynamic Stabilisation Technology ('DST™'), Hadrian X measures movement caused by wind, vibration and inertia and counteracts it in real-time using advanced algorithms to provide unprecedented precision. Its unique control system uses CAD (Computer-Aided Design) to create a 3D model of the building design, which is then used to calculate the materials list and tell Hadrian X what to build – all with precision.

Hadrian X builds walls using the Fastbrick Wall System, made up of uniquely designed blocks and adhesive for continuous construction. The blocks are approximately 12 times bigger than standard house bricks and are lighter, stronger and designed to minimise waste. They are fused together using a special adhesive, which bonds in just 45 minutes, holds stronger and results in greater thermal and acoustic properties than traditional mortar. No more lost days waiting for mortar to dry with this continuous construction method previously not possible with traditional approaches.

Key Success Factors

- **The technology.** DST™ delivers accuracy previously only achievable with indoor robots, paving the way for robotic automation outdoors. Dynamic Stabilisation Technology (DST™) reacts to wind, vibration and other environmental factors instantly, enabling precise positioning of objects over large distances outside. Therefore, it could be used also in other sectors in addition to construction.
- **The cost model.** Because of the fast advancement of digital technologies, cost trajectories are in favour of the adoption of the new bricklaying robot Hadrian X. The Hadrian X builds from a 3D CAD model with an exact bill of materials, producing far less waste than traditional construction methods. Furthermore, the Hadrian X is capable of building the walls of a house in as little as a day, with full transparency of the project plan before commencement, leading to a reduced building cost and a potential solution to the global housing affordability crisis.
- **Partnerships.** In order to further the commercialisation and reach of its ground-breaking technology, FBR has signed several key agreements. In July 2017 FBR announced it had entered into a Memorandum of Understanding with Caterpillar Inc. to discuss and develop a potential framework for collaboration regarding the development, manufacturing, sales and services of the Hadrian X. This MoU was recently extended to January 2019. FBR also announced it had signed a MoU with the Kingdom of Saudi Arabia's Ministry of Housing, contemplating the construction of a minimum of 50,000 new home units in the Kingdom of Saudi Arabia by 2022, indicating approximately 100 Hadrian X units would be required to complete this objective. In June 2018 FBR announced a Strategic Collaboration Agreement with GP Vivienda in to discuss pilot testing programmes for the Hadrian X in Mexico, as well as opportunities for future applications of DST™. In September 2018 FBR announced it had entered into a Global Partnership Agreement with Wienerberger AG, the world's largest clay block manufacturer, to jointly develop a clay block optimised for use with the Hadrian

X, with testing to take place in the form of a pilot programme in Europe.

- **High Compatibility**. The technology is compatible with other solutions provided by digital technologies, in particular with 3D printing and offsite building.

Barriers to innovation

When this innovative solution was first conceived in 1994, computational capability was insufficient to carry out the required tasks of the Hadrian X to an acceptable standard. Moreover, the cost at the time to bring this new technology into existence outweighed the potential return on the investment due to the expense associated with the technology and the lengthy development time required.

The construction industry has historically been resistant to change and innovation, however as market conditions changed significantly and the technology improved to the required level where it was capable of carrying out the necessary processes to deliver on the purpose of the invention, development of the early Hadrian prototypes commenced.

In order to sufficiently scale a new technology a number of prototypes need to be developed to prove that the technology is ready for mass production and adoption. FBR initially demonstrated wall building technology using ground-mounted robots and mortar, before developing the Hadrian 105, the precursor to the Hadrian X and the first construction robot to build a multi-room brick structure from a 3D CAD model.

FBR then commenced the design, procurement and assembly of the Hadrian X, its current commercial prototype. The Hadrian X is fully assembled and operational, and the functionality of DST™ with the Hadrian X has been proven through a two-stage testing process. The Hadrian X has commenced the Factory Acceptance Testing ('FAT') phase, where it will build structures in different configurations within a controlled factory environment. Upon satisfactory completion of FAT the Hadrian X will build its first 3-bedroom, 2-bathroom structure, presently scheduled for completion before the end of the 2018 calendar year.

Lessons learned

- **Need for a clear business case.** The push for the adoption of the new technology came from a change in market conditions that for the first time made the return on the investment much clearer, thus leading to a significant market opportunity for the new solution to be adopted.
- **Versatility**. Hadrian X's core technology (DST™) goes beyond the needs of the construction sector, it's versatile therefore could have practical applications also in other fields (e.g. agriculture).
- **Iterative approach and the company's philosophy.** The company first developed a technology demonstrator, then a commercial prototype, and will continue to refine its technology in preparation for mass production and adoption already having achieved proof of concept. This approach has two key benefits in that it increases confidence on the future client's side as well as allowing for continuous improvement of the product before scaling it up.
- **Collaboration**. Striking deals with a variety of different partners worldwide has enabled FBR to better understand the market dynamics so as to improve the product while making it highly adaptive to the environment thus favouring higher integration with other digital technologies and processes (i.e. off-site building).

7.7 The Electric Site

The Challenge

Operations in the quarry industry haven't changed in years and they suffered from high inefficiencies thus opening the way for the research on new and innovative forms of innovation. In particular, processes in the quarry industry tend to be highly fragmented. As a result, any electrification effort to reduce CO2 emissions and improve energy efficiency runs the risk of being only partially successful as improvements, even if substantial, stay limited to a specific segment (i.e. improvement on a specific machine). In such a scenario, there was the need to look at the quarry operations from another angle and to map the entire processes thus taking into account the dynamics of the entire ecosystem so as to improve the overall efficiency in the quarry site.

The solution

Volvo CE teamed up with its customer Skanska Sweden, the Swedish Energy Agency and two Swedish universities – Linköping University and Mälardalen University – in October 2015 to collaborate on the SEK 203 million project. The objective of such a partnership was to turn the quarrying industry upside down in a groundbreaking study to create the world's first 'emission-free' quarry.

The project has involved developing new concept machines, work methods and site management systems which together, form a complete site solution. New technology encompasses machine and fleet control systems and logistic solutions for electric machines in quarries.

The project aims also at rethinking the way we look at upon machine efficiency – pushing the boundaries of the competence. As a result:

- Three rigid haulers, for example, have been replaced by eight smaller prototype HX2 autonomous, battery-electric load carriers to transport the material from the primary mobile crusher up to the secondary static crusher.
- The primary crusher on the Skanska site is loaded by the 70t dual-powered, cable-connected EX1 excavator prototype. The base machine for the EX1 is a Volvo EC750 model that has been upgraded to incorporate an electric motor in addition to the diesel engine
- The piles of material on the site are organised by the LX1, Volvo CE's prototype electric hybrid wheel loader. The machine can deliver up to a 50% improvement in fuel efficiency, as well as significant reductions in emissions and noise pollution compared to its conventional counterparts. The LX1 is a 'series hybrid' that incorporates a driveline that consists of electric drive motors mounted at the wheels, electric-driven hydraulics, an energy storage system, a significantly smaller diesel engine and new machine architecture, including a new design of the lifting unit. It is this combination that enables the substantial gain in fuel efficiency.
- An activity has been completely eliminated from the set of operations. In a "standard" non-electric site the loading of loaders is performed by letting the material falls down on the ground from the belt conveyor from the crusher, then the material is left up again with a wheel loader and loaded on to a dump truck. In the electric site conceived by Skanska, Volvo, the Swedish Energy Agency and the two Swedish universities the autonomous trucks are loaded autonomously from the belt conveyor, eliminating one operation and contributing to improve efficiency.

Key Success Factors

- **Data management tool.** The machines used as a part of Volvo Construction Equipment's (Volvo CE) electric site research project are controlled by a site management system called Site Assist. The system has three main functions: it controls the overall operation at the Electric Site (e.g. choosing which automated machines should be active and what the different machines should do); it provides insight into production KPIs, such as how much material is being produced; it acts as the integration point of data between all the various units and systems being used on site.
- **Improved security.** The fleet and traffic control modules ensure that the machines are doing the right things in the right spot, and that they maintain sufficient distance from one another throughout the different work steps. This helps to ensure safety on site.

- **Improved efficiency.** The new solutions proved to be successful under several aspects, such as optimization and planning, electrification, automation and safety. Production will run for 10 weeks and has been designed to achieve the same output as Skanska's usual equipment but, crucially, with up to 95% lower carbon emissions and up to 25% lower total cost of operations.

Barriers to innovation

- **The mobility-efficiency trade-off.** The automation of the machinery is acquired thanks to the design of specific routes in the quarry. Electrified hauliers and excavator bartered their mobility for an improvement in efficiency and reduction of emissions, due to electric-fuelling.
- **Costs.** Volvo CE says that electric machines will soon have enough power/charge to be viable over a demanding day-long work cycle. However, even if electrification helps to bring down operating costs, the initial capital investment is still hefty.
- **Battery life.** One constraint on electrification has been battery life. Volvo CE says that electric machines will soon have sufficient power/charge to be viable over a demanding day-long work cycle.
- **Need for new skills.** The automated quarry demands new skills in the operators. Some of the new machines, such as the hauliers, are driverless. Operators must be good at coordinating and planning rather than be sitting in the downtruck and moving around.

Lessons learned

- **Data management is key to reach the outcome.** The "zero emission" target requires an ecosystem approach that takes into account all the processes and the operations in the quarry site, which can be guaranteed by the use of the data management tool "Site Assist", that favors the real-time monitoring of operations onsite.
- **New skills are needed.** The operators sitting in a truck will be sitting in an office instead, acquiring new abilities for moving the trucks, monitoring the routes and the data derived from the machines, and so on. This implies that new competencies need either to be found and or created in the future
- **Collaboration is the key.** Volvo CE is coordinating the project and is in charge of developing the machines and systems. Skanska Sweden is providing logistical solutions, application relevance and job site knowledge. The Swedish Energy Agency is helping to fund the project and the universities are carrying out research. Two PhD students are looking at battery aging and energy management for electric vehicles, as well as functional safety. Such kind of partnership could be one way to proceed with costly electrification projects.
- **Public funding is important.** The Swedish Energy Agency is providing SEK 65 million (it has awarded SEK 59 million to Volvo CE, SEK 5 million to Linköpings universitet and SEK 1 million to Mälardalens högskola) in order to favour the transition towards a sustainable model, that is costly for private companies.

7.8 A Brand-Independent Collaboration Software

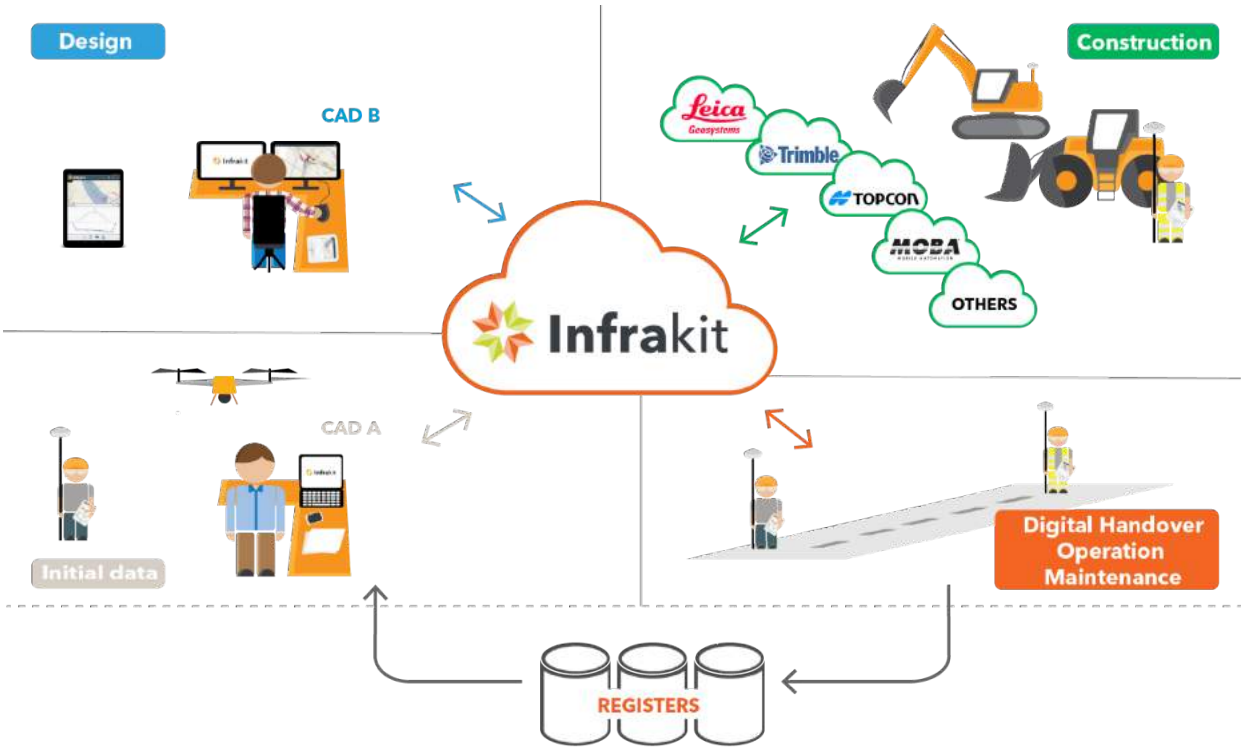
The Challenge

Progress information in infra-construction is often slow to circulate among the actors involved in the project and this can lead to machinery standstills, waste of time and expensive errors conducted by operators who don't have information on the project and its progress at the right time. Sometimes, those who work in a project get to know its progress weeks or even months later. The unavailability of information at the right time can cause major losses to the infra-construction sector.

This can also be caused by the fact that normally contractors have a mixed fleet with machines with machine control from different brands. As each machine-control supplier works with its own data format, it gets difficult to gather uniform data from the machines for further use and operators usually search for the information needed in outdated paper pdf documents.

The solution

INFRAKIT B.V. has elaborated a brand-independent collaboration software able to acquire data on an infra-construction project and distribute it, to make actors keep track of project progresses. All the information is stored in a single cloud platform and it can be accessed in real-time by subcontractors and other relevant people (see image below). To do so, there is no need to install the software but it is sufficient to have internet access and a browser.



Source: INFRAKIT B.V. ***https://infrakit.com/en/***

INFRAKIT B.V. software acts as an intermediary absorbing information from the field and distributing it at the right time, in the right place and data format. Moreover, thanks to the INFRAKIT's GIS features, users can be shown on the project map so any user knows where they are in the design model.

The INFRAKIT B.V. App (or the mobile version of the internet application) allows accessing the information available on the cloud platform and is able to add information like measuring data, pictures and documents to the project.

The following content can be uploaded and shared through the INFRAKIT B.V. cloud platform:

- Project's open-format infraBIM designs
- Infra-project progress information
- Data from machinery and equipment
- Geo-referenced photos (INFRAKIT B.V. is able to automatically tie them to the exact coordinates)
- Documents, intelligent project data and photos for digital handover documentation.

All the data uploaded in the INFRAKIT B.V. cloud platform is stored in secured servers and its connection deploys state-of-the-art security.

Success Factors

- **Project progress information is available everywhere and at any time.** INFRAKIT B.V. cloud platform stores all the information of the infra-construction project in one place which can be accessed via devices (tablets, platforms) without being tied to time and place when monitoring the overall project progress.
- **Information is uniform**. Having all project data stored in one place and accessible via the cloud platform, the software allows the relevant actors (designers, project directors, site managers and machine operators) to have the same updated information.
- **Projects are completed with better quality within schedule.** Project actors can monitor the project progress and manage the quality control, have a view on their machine-controlled excavators and as-built points being gathered through their PCs or mobile devices in real time, increasing the overall quality of the project and saving time. For instance, having a centralized design management and synchronization in the work machines and centralized collection of as-built data saves 50% of the survey chief's working time.
- **Costs are reduced.** Thanks to the INFRAKIT B.V. cloud platform, human errors are reduced and the time is saved bringing up to 20% of costs saved.
- **Failure cost reduction.** INFRAKIT B.V. prevents cost related to fails made by working with paper information or former procedures. By centralizing the latest information and distributing only the right data this reduction can save up to 12% of any infra projects cost.

Barriers to innovation

- **3D modelling is not fully deployed by all companies yet.** In many areas companies are still not used to work with 3D modelling and tenders do not always mandate the use of 3D designs.
- **Internet connection is not accessible everywhere.** Some regions still lack infrastructure that allow a stable internet connection; this can represent a barrier for the full deployment of the INFRAKIT B.V. cloud platform and for leveraging on its collaboration features.
- **The sector needs more awareness on transparency.** There is the need to increase awareness about the benefits of higher transparency in order to enhance processes and operations.

Lessons learned

- **Data sharing is a key element.** Storing all data of the project in a cloud platform allows all actors to be updated in real-time on project progress and reduces mistakes caused by misunderstanding, contributing to and increasing the overall quality and effectiveness of the project.
- **The ecosystem approach is essential for a better decision-making process**. By being able to bring together all players involved in the same environment and by collecting and analysing data from the different project processes, actors have a wider and up to date picture of the project. This is fundamental to make informed decisions while enhancing the project quality.
- **The "openness" of the cloud platform is a plus.** The INFRAKIT B.V. platform is built following a "brand-independent" approach, enabling it to gather and distribute data from different sources of

various brands and store it in one place, without the need for operators to search the information in different data storages. This helps getting additional insight and a wider view on the project and its progress.

- **The use of 3D modelling is a key element.** The access to the design model via mobile devices (through the dedicated App) and PCs ensures that every element of the building frame is set out in the right way and in the right place, reducing possible mistakes.

7.9 The Connected Jobsite

The challenge

The construction sector is highly affected by demographic issues. Firstly, there is a general lack of human resources due to the decrease in birth rate and the ageing population. Secondly, the introduction of ICT technologies requires new types of knowledge and know-how, therefore jobs offers are often not filled and the sector lacks skilled workers able to use advanced technologies. The construction industry is also affected by a high accident rate. Overall, this leads to difficulties in striving to improve safety, productivity and life-cycle management.

The solution

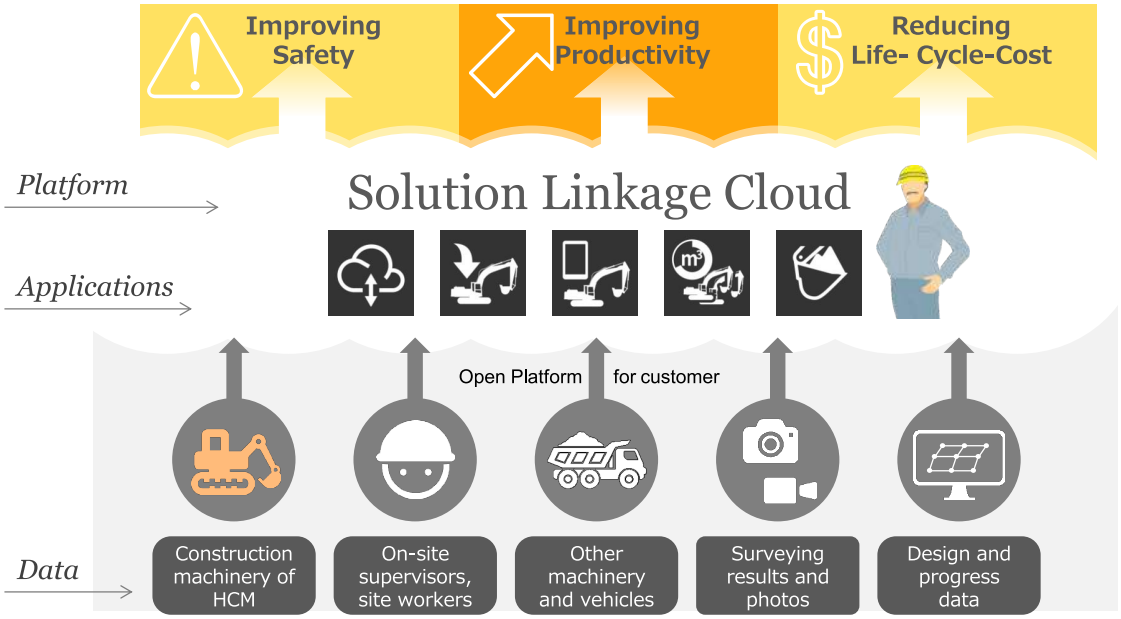
Hitachi elaborated "Solution Linkage", an ICT/IoT solution that works closely with the customer to improve safety, increase productivity and reduce life-cycle costs. Hitachi offers a wide range of advanced technologies within its group centred around Hitachi Construction Machinery (HCM) and adopts an "Open innovation" approach by favouring expert technologies with business partners. Operationally, Solution Linkage can connect the jobsite and gather data coming from operations (data

collection is facilitated by a higher level of automation) to be streamlined in order to support the customer in overcoming the abovementioned challenges. Solution Linkage does not connect one jobsite, but connects a whole network of jobsites so as to increase effectiveness.

Source: The connected Jobsite (Hitachi Power point presentation)

In particular, Solution Linkage incorporates the following technologies (see image above):

- **Solution Linkage Assist:** through the Solution Linkage Assist, Hitachi machine control/machine guidance technologies are interactively connected with on-site operations.
- **Solution Linkage Cloud:** The site information obtained through ICT is shared in the Solution Linkage Cloud, a secure and open cloud where companies can contribute to the overall on-site productivity. The cloud relies on historic data of the machine and enables companies to share their 3D design data with other companies and tools (as shown in the image below). The generated 3D data is then downloaded to ICT construction machines through the cloud and jobsite progress can be monitored at any time.



Source: The functioning of Solution Linkage Cloud

- **Solution Linkage Mobile** (rolled out in Japan in 2018): a mobile device that can be installed in the construction machinery (regardless of the machine's brand) and accessed by the operator through a smartphone. The mobile device can identify the position, understand the work volume and progress and notify approach. Solution Linkage Survey (scheduled to be offered in Japan in December 2018): through the combination of a smartphone and a GNSS antenna, Solution Linkage Survey can measure the volume of earth without needing a specialized knowledge but by simply shooting the object and transferring it to the cloud. It is useful to determine the number of dump trucks for moving dirt and reduce costs.
- **Solution Linkage Wi-Fi** (Rolled out in Japan market in September 2018): An easy-to-install solution, aiming at improving and expanding mobile communication environment even in areas where communications are difficult, such as bridges, highways and dam sites.

The key success factors

- **Improving worksite efficiency significantly.** ICT construction machinery support the work carried out by operators contributing to more consistent operations. The type and functionality of machinery can be enhanced according to the customers' needs.
- **Improving onsite management.** In the phases of surveying, construction, inspection and delivery, data is collected and shared via the cloud. The data exchanged in the platform allows a more efficient management of on-site progress from off-site. The on-site progress can be monitored thanks to the connection of ICT construction machinery in a network, starting from construction history data. Information on the location of construction machinery, dump trucks and on-site personnel can be monitored through a smartphone. Moreover, a simple site survey can monitor the daily progress even for tasks performed with standard construction machineries. Besides having reporting results, correction instructions can be communicated immediately and when a change is made it is shared to the machines in real time, thus ensuring a smooth unified on-site management.
- **Increased on-site safety.** ICT tools can reduce the workload and the number of workers on site, increasing overall safety.
- **Mobile communication is accessed even in non-accessible areas.** Thanks to an ad hoc solution, mobile connection can be extended to those areas where the connection is normally non-accessible and ICT can be used everywhere.
- **A versatile solution.** The functionality of Solution Linkage can be also extended to other jobsites than those of civil engineering and adaptable to other industries (also beside the construction one), such as mining, quarry, dredge, demolition and forestry.

Barriers to innovation

- **Lack of skill sharing.** For what concerns the training part, trainees need some good model case to understand effect and purpose of learning. It's not enough explaining what the new technology is and how to operate it. Obviously they require hands-on experiences which are accumulated by pioneer experiences on real job sites. For operation, inexperienced engineers at digitalised construction need support from trainers. In fact, there's the need to spend a considerable amount

of time to adopt new tech into each work process so as to avoid mistakes. The correct use of new tools requires plenty of preparation to choose the target, the situation and the job site on which you'll try them. Although, even if the number of experienced engineers is limited, you can leverage their experience, time and support with skill sharing so that you penetrate internally new tech as own skill.

- **Shortage of IT/OT literacy can be a big challenge.** In these days the word of "IT" covers more and more categories. Many business people may be wondering why they feel the shortage of ordinary IT knowledge or initiatives even though their IT department is growing. Or some small to medium contractors might not have established yet a dedicated IT organization. Sometimes, even if they utilize various softwares or sales and account systems for the digitalized construction (and BIM is often said to be "IT" too), nobody is in charge of controlling IT tools comprehensively. Digitalisation creates huge data which includes memories of as-built, deliverables and so on. IT can help them to organise, stock, manage and share among relative persons. If IT is meant to save time for the abovementioned activities, there's the need to grasp the processes of digitalized construction. To understand the processes, Operation Technology will be also helpful. It requires that the both of user side and IT engineer side engage in together. Then the problem could be whether you have some reliable partner close to you or not.

Lessons learned

- **Data sharing and ecosystem approach are key.** Having all the information stored in one common cloud platform makes results in efficient operations and seamless on-site management. The combination of the technologies involved in Solution Linkage allows the connection of all the elements involved in the jobsite. Machines, on-site personnel and the information gathered and streamlined by the cloud platform are accessible everywhere (thanks to the extension of mobile connection).
- **Co-creation is key to provide value.** Solution Linkage offers customers a bundle of solutions adapted to its needs and requests. With Solution Linkage, Hitachi is providing higher value to the product it delivers to its customer (machines), working closely with the customer itself and its partners following a co-creation approach.
- **Open Innovation approach is an important aspect for the potential of data sharing.** The Solution Linkage cloud platform has been designed to be open and accessible by anyone who wants to join it. The fact that this solution is adaptable to other brands than Hitachi allows a comprehensive view of operations benefiting the whole site management through a bottom-up approach.

7.10 Telematics in Mixed Fleets

The Challenge

OHL is one of the largest international contractors specializing in the construction of hospitals and railways. Operator safety, equipment security and machine health are at the top of OHL priorities. Having a mixed fleet of heavy equipment and machines, OHL didn't have a way to verify properly, or even document efficiently, machine use and maintenance.

Without appropriate control and useful information, construction equipment may be stolen (as in the construction business, there is usually a master key that turns on every machine) and some machine maintenance is unreported or skipped entirely.

The solution

To proactively solve problems related to unauthorized machine use and timely servicing, OHL implemented Trackunit telematics system in its mixed fleet.

Trackunit telematics keeps OHL's fleet within its control. The new system has provided the company with a solution to its security and safety issues. With the Trackunit system, the company uses a keypad on a portion of the fleet to activate and deactivate the machine, preventing unauthorized use.

Employing the keypad access feature also prevents theft. OHL asked Trackunit to create geo-fencing and zone alerts to ensure that equipment managers know every time if a machine travels out of a specified area.

The Trackunit system has increased the company's ability to track machine hours-of-use, every day. If a machine hasn't been in use for a certain amount of time, OHL moves it to a new job site. Also, thanks to Trackunit telematics, the company is now able to pull maintenance reports and discover potential breakdowns in its existing maintenance plan.

Key Success Factors

- **Improved safety and security.** OHL maintains control of the machine. The company prevents unauthorized machine access using the access control keypad, improving overall safety and security.
- **Real-time control of machines.** Through the GPS, OHL can follow each piece of equipment and know exactly where they are at any time. Site managers know if machinery moves out of predetermined zones or if they are in-use outside of established working hours. The company also knows if a machine has been out-of-use for too long so it can be moved to another job site to serve other purposes.
- **Save time and money.** Gaining control of machine use and maintenance saves the company a lot of time and money. Machine lifetime and safety improves through proper service. Managers know the location and deployment of each machine on the job site.
- **Optimized maintenance.** Scheduled equipment maintenance increases lifetime hours, performance and cost-savings. Maintaining the equipment on-time has meant that the amount of work performed by each machine has increased, saving OHL time and money.
- **User-friendliness.** The Trackunit system is easy to install and deploy. The hardware is placed internally with no external antenna – potential thieves cannot trace the antenna to find the box and remove it (to lose the tracking of the machine).

Barriers to innovation

- **Time.** Projects have active contractors onsite, making finding the time for implementation a little difficult. The crew was always working so coordinating implementation meant finding time during off-hours to install Trackunit systems. Trackunit worked with OHL's schedule to install the system.
- **Everyone isn't always excited to adopt the technology.** Some second-level managers didn't understand the benefits of telematics and the communication it provides every stakeholder. It seemed easier for OHL employees to ask questions of others rather than use the technology in their hand. The solution was easy. When questions were asked, they were referred to the Trackunit system in place with all of the answers. Soon, everyone used the technology and were very happy with the results.

Lessons learned

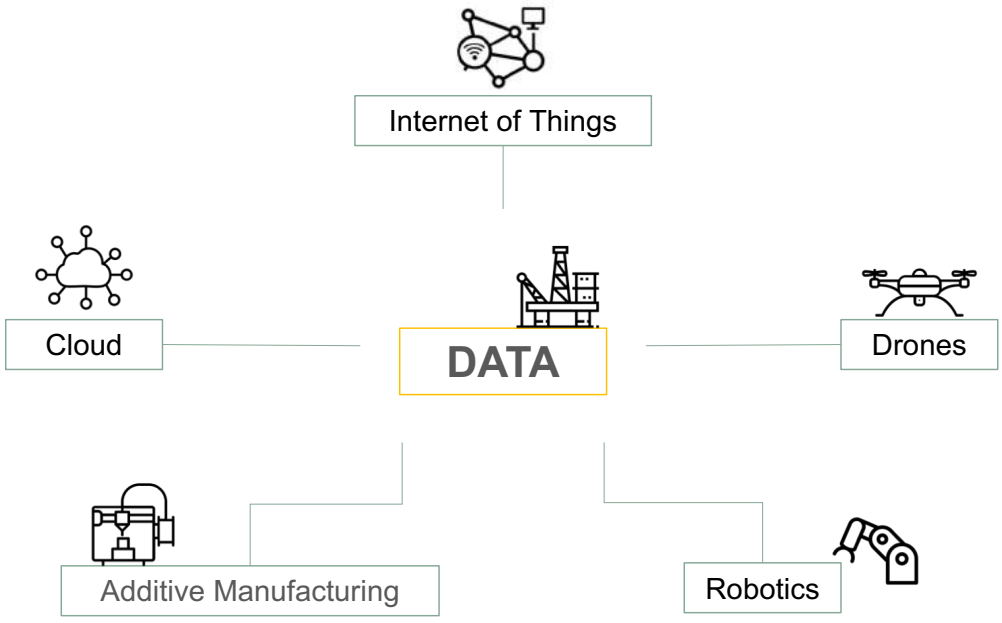
- **The Identification of clear need is critical.** The Trackunit system is a solid response to specific problems OHL faced - the need to improve security (preventing unauthorized accesses to machines and thefts) and productivity through optimized use and maintenance.
- **Digital technologies contribute to higher efficiency.** By installing the Trackunit telematics system in its mixed fleet, OHL was able to improve control of its equipment. Thanks to access control and the ability to keep constant track of machine movement on the job site through the GPS signals, OHL has optimized machine safety, security and use.
- **Pull maintenance reports and discover potential breakdowns.** Through Trackunit's telematics systems the company is now able to pull necessary reports and prevent possible problems. OHL receives maintenance alerts which have increased productivity, reduced costs and saved time.

Conclusions

The research project promoted by CECE aims at investigating the phenomenon of digitalisation in the construction sector so as to gain a better understanding of its dynamics and evolution in years to come.

Methodologically speaking, the project adopts a comprehensive approach to the subject by analysing risks and opportunities related to the adoption of digital technologies by focusing on the following areas: business models, relationship with public authorities and regulatory bodies and skills and competences. The project has been constantly supervised by a Steering Committee that saw the participation of members from the entire value chain – OEMs, rental companies and contractors –who contributed to the project by helping identify companies for the interviews and case studies, revise questionnaires, monitor and approve the overall results.

From the research, it emerges that "digitalisation" is a much wider concept than the adoption of digital technologies per se, as it has to do with the role technologies play in reshaping organizations, processes, products and services. One feature was identified as the common denominator of digitalisation: data. Digitalisation therefore means accessing information to gain insights and to leverage the "power of information" that derives from the collection, analysis and management of data to provide new solutions with a higher value added.



Source: ID Consulting and S.I.RI.O.

Overall, digitalisation tends to be perceived as a very promising opportunity for companies in the construction sector to enhance their competitiveness in the future. From the analysis of interviews and case studies it emerges that digitalisation is a pervasive phenomenon that can generate a positive impact in the following areas

Area	Objective	Enabling Technologies	Data sources
Product/Service	• Enhancing the performance of vehicles • Providing new technical and non-technical solutions (*servitization*)	IoT/Robotics	○ Construction Equipment ○ GIS
Revenue Model	• Increasing productivity • Improving resource management • Improving processes and operations on-site and off-site • Rethinking business models	IoT/Robotics/ Drones/AI/Additive Manufacturing	○ Logistics ○ Construction Equipment ○ Weather ○ GIS ○ BIM ○ Project
Environmental sustainability and safety	• Reducing CO2 emissions • Diminishing waste • Reducing workload and exposure to dangerous activities	IoT/Robotics/AI	○ Construction Equipment ○ GIS ○ Logistics Data

A comparative analysis with other sectors that have similar characteristics (agriculture and commercial purpose vehicles) shows that there are common elements in the digitalisation process that could be taken as an example and (at least partially) followed when drawing up a strategic plan for digital transformation in the construction sector (i.e. data sharing and data management, servitization, standardisation). In certain aspects, the construction sector still has some way to go. At the same time, the example of agriculture demonstrates that arriving late is not necessarily a bad thing. On the contrary, it provides the possibility of catching up much faster with other sectors leveraging on the existent technical and managerial know-how. In the end, it's worth quoting one interviewee who said that "once the journey has begun and companies have taken the first step in digitalising their business, there is no way back."

The value of data

Awareness regarding data and techniques to extract value from data – which is closely related to the adoption of other technologies such as IoT, drones, cloud – is of paramount importance in order to facilitate the process. Greater knowledge of such a disruptive phenomenon as digitalisation will also stimulate actors to embrace change as a greater awareness of risks and opportunities means (potentially) a higher level of acceptance.

A set of possible recommendations has been identified in order to accelerate digitalisation in the sector.

1. **Identify a business case through a multi-step iterative approach.** Identifying the right business case is by far the most important trigger for digital transformation. Before facing the challenges of digital transformation, companies want to fully understand what advantages digitalisation will bring to their own businesses. For this reason, a multi-step iterative approach proves to work when attempting to stimulate digital transformation in organisations.
2. **Use digital (data) technologies to identify needs/problems.** Collecting, integrating and crossing large datasets from processes and operations can help better investigate problems and inefficiencies in the construction site of the future, thus leading the way for the provision of research into new outcome-based solutions. Having access to data and knowing how to use it is a fundamental precondition for new opportunities to arise and for the identification of the business case.
3. **Adopt an ecosystem approach to look for outcome-based solutions.** The gradual shift towards a servitized outcome-based business model that concerns all parties of the construction sector means monetizing services that can be offered to end-users by leveraging the potential of data analysis. In order to provide them with outcome-based solutions, there is the need to use data analytics with the aim of investigating the dynamics of the ecosystem as a whole so as to determine a priori the potential costs and returns of adopting innovative solutions (products and services).
4. **Focus on data-sharing agreements.** The potential (and the derived risk) lies in the use of data, not in its ownership, so to reap the full benefits of data analysis, there is the need to reconcile the interests of all the parties in the value chain by finding new agreements on data sharing. Several successful examples of data-sharing and data-management already exist both inside and outside the sector that could be used as a model for the discussion.
5. **Increase collaboration.** New forms of collaboration among all parties in the value chain and in the IT sector are already arising as a result of the increased interest in the collection and analyses of data about processes and operations with the aim of improving the overall efficiency of the construction site. The gradual shift towards an ecosystem approach requires stronger collaboration among parties to provide successful solutions.
6. **Stimulate new forms of public support for digitalisation.** New industry-driven funding schemes in support of the digitalisation of the construction sectors at EU level – i.e. PPPs and/or Joint

Undertakings – that foresee a joint effort from the public and the private side can be a powerful tool in accelerating digital transformation and harmonizing the initiatives carried on at national level. This would partially relieve the construction industry from investment costs that they may sustain thus freeing resources for SMEs so as to accelerate their digital transformation.

7. **Find the right balance between the "pull and push" approach.** Best examples of digitalisation occur when governments in public procurement find the right balance between mandating the adoption of digital technology (push) while reducing burdens (i.e. tax breaks, incentives) to companies that take the digitalisation path (pull). For this to happen, close collaboration between the public sector and the construction industry is needed. In that sense, the public sector can help by encouraging and supervising the standardisation efforts among the parties.
8. **Strengthen training and education**. Considering that skills will gradually change as a consequence of digital transformation, new forms of collaboration with universities and VET schools for the creation of educational programs are encouraged. The new programs on one hand will serve the objective of equipping current and future employees with the necessary technical and digital skills while on the other hand addressing the need to create a new class of executives capable of leading organisations in the new digital scenario.

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COMMITTEE FOR EUROPEAN CONSTRUCTION EQUIPMENT

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