

# National and International Impact of Digitalisation on Workers in Construction

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**National and International Impact of  
Digitalisation on Workers in Construction**

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# A. Study

## 1. Summary of the results

The **impact of digitalisation** on the construction industry will be far-reaching. It will affect all the companies and stakeholders involved in the construction process for the entire lifecycle of every building. It will transform the everyday work of every trade and profession on the building site. Whereas previous scientific studies have tended to focus on the impact of digitalisation at the corporate level, this study explicitly highlights the impact on construction workers. More concretely, it should enable us to react proactively to the upcoming and partly disruptive developments facing the construction industry and to prepare workers on building sites to deal with these developments as positively as possible.

While information management on today's building site is still dominated by printed plans, written documents, lists of every possible scale and countless e-mails, tomorrow's most important information will be retrieved from – and fed into – a 'common virtual workspace'. Access to this workspace will be facilitated by 'smart', mobile devices such as phones, tablets and 'augmented reality' glasses. The building will be assembled in a 3D-BIM model in a collaborative process involving all project participants and everything that the site personnel require in order to realise the building will be retrievable digitally. This should significantly improve the quality of the design, execution and operational processes but it also means that new and more complex demands will be made upon workers on building sites. And one particularly significant result of the digitalisation of processes on building sites will be the emergence of new job profiles.

Today, building materials and components are often still managed and handled in an analogue manner that is time-consuming and prone to error. Tomorrow, the ordering and scheduling of materials – especially at the interface with suppliers and other trades or between the building site and the storage facility – will take place on digital, contract-independent collaboration platforms that have access to central databases and are supported by technologies such as robotics. Routine activities should proceed as a series of standardised process steps, relieving the burden on construction site workers.

Today, the image of the building site is still one in which a relatively high numbers of workers carry out a wide range of functions. Tomorrow, an ever increasing number of standardised components will be produced in factories or in prefabrication areas on site and then assembled in situ, supported as much as possible by robots and partly autonomous machines.

Today, communication is still largely based on talking together. This will remain just as important tomorrow. Meetings, run in a spirit of respect and focussed on finding solutions, will always make the decisive



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contribution to the success of a construction project. But some of tomorrow's communication will be digital and take place between 'smart' devices or even, directly, via the 'Internet of Things'.

And tomorrow, the conclusion of the construction period will leave us with not only the building itself but also its 'digital twin' – an exact 3D-portrayal of reality with additional information, to which all workers on the construction site will contribute and which can be used by all project participants, right through to the facility managers.



The picture of the future is very complex because the construction sector is undergoing a transformational process whose outcomes cannot be predicted in any detail. Regarding the sociological aspects of this transformation, for example, there is very little previous research to which one can refer. The **objective of this study** was to holistically analyse and assess the technological developments and impact of digitalisation on work in the construction industry as a means of drawing up recommendations for action.

Special attention was paid to the **development of job profiles**. Some completely new areas of work will emerge, as exemplified by the key role of acting as hub between the digital and the real worlds or as 'the human manager of the robot'. The focus on 'upstream execution design' will intensify in future. 'Think before you start' will also be a basic premise for construction workers, while construction process planning will play a much more significant role. Today's de facto "standardised improvisation on the basis of a design process which accompanies progress on site" will become yesterday's solution, while the increased quality of planning will enormously improve the work-life balance of the construction worker. But not everything will go as planned. It never does. This means that the experience of construction workers will become even more important as they have to deal with short-term changes, solve problems and take emergency action. Thanks to our ability to swiftly understand complex interrelationships on the basis of which we can then take instinctive decisions, humans will always have an advantage over robots.

At any rate, digital skills must form part of the **education** of every trade or profession. And it must also be ensured that the construction industry introduces apprenticeships focussed on digital aspects and the relevant technologies. *Digitalisation must not be allowed to become the exclusive province of IT-experts and graduates.* Due to the speed of developments, 'on-the-job training' will be an important subject. This will make new demands on education but also require a new approach by companies. Life-long and, hence, on-the-job learning will become a fundamental aspect of our lives.

It is to be feared that the number of jobs for unskilled workers will decline or that these will be taken by cheap labour from other regions. More generally, digitalisation will lead to the globalisation of many

processes relevant to the construction industry, or at least make these processes much less location-specific.

The **labour market** will also change demographically: For example, many more women will be found on building sites and we will all work longer. However, this will not eliminate the shortage of skilled workers. We must see this as an opportunity. We must introduce a broad bundle of measures – image campaigns that sell construction work as a high-tech occupation, concrete education and training, mobility support programmes and targeted international publicity – designed to position the construction industry as one that offers a range of attractive career models.

The **organisation of the working process** is becoming a central question. Is there a tendency to see automatised as a series of compartmentalised, predefined implementation processes in which workers are no longer required to have an understanding of the whole, as a result of which such work will slowly be taken over by less-qualified and poorer paid individuals? Or will it be organised on the basis of teamwork in functionally flexible organisations in which workers with different qualifications and skills work together in teams? Technology does not necessarily need to drive this process – but it provides the flexible context that workers' representatives and companies can actively shape together.

IT will become the backbone of this way of organising work – affecting all phases, participants and levels of construction processes. But the professional lead must always be taken by the relevant construction experts. And this means the entire spectrum of specialists in all relevant disciplines and levels – from the expert manager to the practically experienced worker. Only such integration will make it possible to leverage the potential of digitalisation for successful building projects. The objective of this development is yet to be defined in detail. But this is the major opportunity: Digitalisation is a collaborative process for finding solutions in which workers should directly participate. Companies and trade unions should work together actively to this end and discuss, as equal partners, the upcoming new demands on companies and their workers.



The looming developments in society – the ‘two sides of transparency,’ with all its opportunities and threats for individuals – require a completely new policy approach, in particular in the social field.

For this reason, the study draws up **recommendations for action**, which cover a broad range of areas of action. A wide variety of subjects must be addressed, from the political, social and legal parameters, corporate and project processes, ProCS – Procurement, Contract & Settlement, digital tools and the interoperability of software solutions to research & development and education & training.

*A serious, committed social partnership could be given a new lease of life by the digitalisation of the construction industry.* While today's key concerns are wage negotiations and working conditions, the future focus of the partnership could be the joint design of this new working environment, which can offer new, better working conditions and an improved ‘work-life balance’ based on a largely plannable working day and remuneration levels that are in line with the market. Each side should use digitalisation as a premise and as an opportunity to reinvent politics in the social arena.

In this context, mention should be made of the following selection from the various recommendations for action set out in this survey:

- Joining forces at the domestic, European and international levels because the effects of digitalisation are not held back by national borders and the global interconnection of trade and value creation mean that we are multilaterally dependent upon each other,
- Restructuring and retraining measures and a range of other safety nets, financial and otherwise, are needed in order to soften the blows caused by transformations in some trades and professions,
- A restructuring of models of income and taxation at the domestic, European and international levels, in order to respond to new production conditions and labour forms,
- A digitalisation offensive for SMEs, craftspeople and building professionals in all regions – for these are responsible for the vast majority of construction sector jobs,

- A workshop for the future, which is based on the principles of social partnership and organised together with companies of every size and type, that will address every aspect of digitalisation and automation in the construction industry and develop appropriate measures,
- Data protection should become one of the central preoccupations of the trade unions, without losing sight of the fact that an appropriate level of transparency can also be used to protect jobs (in which case initiatives such as the 'Baucard' – an electronic card designed to record the presence and activity of workers on a building site – should continue to be developed).

We must recognise that we find ourselves in the middle of a process of transformation. We are faced by new input every day and there are many areas covered in this study for which there is a lack of solidly-based studies that could act as a basis for making decisions.

Developments are taking place at a sometimes breathtaking rate and much persuasive argument is required if everyone is to take part in and benefit from this revolution. More than anything else, this demands clear visions and proactive strategies that can only then be developed and implemented in the context and the spirit of a social partnership. In this sense, trade unions represent an essential partner for employers and should actively encourage both companies and politicians to join them on this journey.

The study should be seen as an opportunity to initiate dialogue at the domestic, European and international levels with the aim of introducing the necessary change. This requires both political will and a political framework. In order to guarantee these, regardless of which political parties hold power, it is essential that workers' representatives develop strategies that emphasise the positive.

If Europe fails to find a new, self-assured and, hopefully, exemplary collaborative approach to the dynamic and balanced reform of its economy and society, other regions will set the tone and there is a danger that many of our cherished and proven values will be lost.



## 2. Starting point and objectives

The **starting point** for this study are the offer dated 12.09.2018, the associated discussions and the resulting commission.

A key **element** of the study is the cooperation and eventual fine-tuning with BHI-BWI in its role as the representative of the domestic and international trade union organisations.

The objective of the study, which is based on scientific research and has been drawn up with the cooperation of national and international trade union organisations, is to analyse and outline the direct and indirect impact of digitalisation on the working environment in the European construction sector and to set out recommendations for action. It will pay particular attention to the opportunities for and challenges to construction workers resulting from digitalisation and to the regional and trans-regional features of each construction market and any ecological impacts (keyword: green energy). Regarding the individual construction sectors, a distinction will be made between the construction of new buildings, the refurbishment of existing buildings and civil engineering and infrastructure projects.

The **focus** of the study is the factor of work in the light of digitalisation from the perspective of workers and, most particularly, of those who require the special protection of trade unions.

In concrete terms, the study focuses on three job descriptions, even when these are sometimes hard to identify in specific sources:

- supervisor (Polier)
- foreperson (Vorarbeiter)
- labourer (Arbeiter)

These job descriptions are collectively labelled S/F/L (in German P/V/A)



The recommendations for action are made at the political and scientific level. These correspond with the following findings and convictions:

- Dealing with the opportunities and challenges of digitalisation and their consequences for the **working lives** of people is, alongside climate policy, the **major global task** facing national, international and, above all, European **politicians**.
- In recent decades, **Europe** has often been a **pioneer** in the areas of social and ecological development and this positive role *should not be lost*. Even if approaches to solutions are very different in different countries these are frequently groundbreaking in terms of social policy.
- **Social, welfare and economic policy** must go hand in hand and develop models for the future together. Historic differences must be overcome. There was a reason and a time for such differences but they do not belong to the future.
- **Theory and practice, politics and society** must be synchronised. Without scientific research into the relevant mechanisms there can be no sustainable success. In the case of two such complex yet interwoven subjects as digitalisation and work the lack of academic investigation and conclusions is particularly noticeable. More concretely, there is an alarming shortage of basic scientific information regarding the future of work on building sites in particular and in the building sector in general.

### 3. Content and working method

#### 3.1. Note regarding gender

The authors attach particular importance to diversity and equality of opportunity. However, in the interests of improved legibility the text may sometimes employ either the female or the male form. This is not intended to imply any sort of disadvantage to the other gender.



#### 3.2. Content and structure

The content and structure of the study are – in keeping with the priorities of trade unions – essentially aligned with the areas addressed in the study “The Potential for Digitalisation in the Construction Industry” (40) and the subsequent “Roadmap for the Digitalisation of Design, Construction and Operation” (42).

This enables the broader areas of investigation to be broken down as follows – on the basis of this roadmap – and developed further in line with the focus of this study:

- Necessary **political and legal parameters** (e.g. joining together of forces; coordination within the DACH Region and across Europe; training plan agreed at the European level)
- **Changes in corporate and project processes** (notions such as digitalisation, the monitoring of workers, transparency, process methodology; best practice examples from factory-based industry, prefabrication, prefabricated components, robotics, 3D printing)
- **ProCS – Procurement (tender/tender award, contract & settlement)** processes for construction projects (how can cooperative construction contracts influence working conditions on the building site?)

- **Tools and the interoperability of software solutions** (which developments are emerging within the industry and how well – or otherwise – do they meet the requirements of the future working environment?)
- **Research and development** (implementation of pilot projects and sample applications, cooperation between research and practice in the realisation of concretely implementable research output)
- **Education and training** (a central concern from the perspective of workers due to the need to prepare the next generations of working people to meet the challenges of the future; continuous adaptation of educational levels and profiles in line with the rapidly changing job profiles of the future)

The study will then address the concrete impact of these areas of investigation on the employees of companies on the European construction market. Finally, concrete recommendations for action will be made in all these areas.

The overall result of this will be to draw conclusions about measures for the future that are essential from the perspective of workers.

### 3.3. Working method and results

The key **phases of development** of this report were as follows:

September 2018	Initial meetings and commissioning
Autumn 2018	Literature research and development of initial contents
January 2019	Discussion with ÖGB BHI in Vienna
February 2019	Workshop with BHI at an international level in Vienna
Spring 2019	Interviews and meetings, further development of the contents
April 2019	Incorporation of contributions from international trade unions
May 2019	Coordination with ÖGB GBH BHI
June 2019	Presentation to the ILO in Geneva

Following a period of intensive research into the relevant literature, discussions with representatives of trade unions in a number of countries began in January 2019; these included both telephone-based and face-to-face meetings as well as workshops and coordination sessions.

The recommendations for action are the work of the authors. They are addressed at **all responsible individuals in the worlds of politics and business across Europe and beyond**.

Even if the authors of this study were focussing on Europe, their **results and recommendations** could also be interesting to other continents and it is important to regularly compare notes globally, especially on such a universal issue. Societies in Asia, Africa and the Americas often deal with the same technological phenomena in completely different ways, a fact that we should not forget, given the context of globalisation. This means that international organisations (trade unions, the ILO and many others ...) bear a very high level of responsibility, which is frequently called into question by a wide range of political representatives.

A native **English-speaking** expert in the field – Rupert Hebblethwaite MA MBA Dip Arch (Cambridge) – was involved from the preparation phase in order to ensure that the German and English versions of the study could be developed in parallel.



Research literature in general, like this study, often contains **examples**, sometimes real and sometimes fictional, as well as quotations from interviews carried out within the industry. One should not lose sight of the fact that research into the subjects of Work-Digitalisation-Building is relatively uncommon and concrete statements are often absent or lack practical corroboration. Both of these drawbacks are typical for such a new, dynamic area of research and underline the importance

of promoting research and development in theory and practice, domestically and internationally, with as high a degree as possible of cooperation and exchange.

### 3.4. Sources and literature

A detailed list of sources with references can be found in the appendix. Some of the sources that are particularly relevant to the study are described here in somewhat greater detail. Given the quantity of sources that were suggested to us or discovered by the authors during the course of their work, it was only possible to process these sources selectively. All of these are, however, presented below in the list of sources, regardless of the extent to which they were used.

- The study “Potential for Digitalisation in the Building Industry” by the Institute for Construction Process Management of Vienna University of Technology, published in December 2017 on behalf of the Federal Ministry for Transport, Innovation and Technology and the Austrian Economic Chambers, Construction Department. Chapter 2.1.3 is devoted to The Substitutability of Specialisations in the Building Industry and refers to further sources.
- The Roadmap for the Digitalisation of Design, Construction and Operation in Austria, final version, September 2018, includes recommendations for action which are adopted here, such as:

R.1-3	Joining forces, in Austria, with neighbouring countries, across Europe and internationally
R.10	Publication of a concrete step-by-step plan with objectives and timetable
P.5	Research into economic and socio-political scenarios for the future
A.5	Optimisation of lifecycle costs as a future focus in tender processes
F.1-3	National and international research plan, pilot projects, research & practice

- In its study “The Digitalisation of the Construction Industry,” dated 2015, 47 Roland Berger highlights the situation in – or the backwardness of – the construction industry and points to successful examples, needs for action and opportunities that must be addressed. The role of work and workers is only an indirect focus of the study.
- The study “Industry 4.0 – an assessment from the perspective of labour sociology” by FORBA (Ursula Holtegrewe, Thomas Riesenecker-Caba, Jörg Flecker) 33, which was dated November 2015 and commissioned by the Vienna Chamber of Labour, positions the discussion about ‘new’ technologies in industry in the context of current sociological theory and describes the areas of activity of advocacy groups, social partners and politicians in this field. This offers interesting approaches, which are also relevant to the current discussion in the building industry.

### 3.5. Interviews, meetings, events, contributions

The following interviews, meetings and events provided important insights, which were incorporated into the study.

Thu. 21.02.2019	Workshop ÖGB GBH BHI European Trade Unions
Wed. 06.03.2019	Professor Jörg Flecker, University of Vienna, W. Reismann
Wed. 06.03.2019	DI Arno Piko, ASFINAG, W. Reismann
Thu. 14.03.2019	Ing. Thomas Prigl, Baufachschule Kargan, W. Reismann
Tue. 26.02.2019	Site Manager Paul Weiss & Foreman Stefan Oswald, Swietelsky, K Breitwieser
Tue. 19.03.2019	Mag. Thomas Riesenecker-Caba, FORBA, K. Breitwieser
Mon. 01.04.2019	Dr. Sarah Buchner, STRABAG, K Breitwieser

Trade union organisations from the following countries contributed to the study: Austria as initiator, Belgium, Germany, the Netherlands, Poland, Portugal, Sweden, Switzerland and Spain.

We would like to take this opportunity to thank the contributors and other interview partners. These conversations were, without exception, highly professional and offered an extremely open and expert



analysis of the issues. The contributions reflect a broad, international perspective and represent a valuable addition to the ideas expressed in the study.

Minutes of the interviews (in German), original contributions by the international trade unions (in their original languages) and presentation documents prepared for the ILO in Geneva (in English) are available from the ÖGB BHI in Vienna.

### 3.6. Core questions

The following core questions underlie this study and the related research activities:

- Which developments will lead to more efficient and effective production in the building sector?
- Which job profiles will change as a result of these developments and how?
- What are the resulting recommendations for action?

The word “efficient” was chosen here very consciously. Without economic incentives it is difficult to implement necessary change. But ‘effectiveness’ is also a decisive quality in any process of transformation.

Finding answers to all these core questions requires personal assessments – which are not always simple and often subjective – of the developments that will result from dynamic advances in technology and their as yet unpredictable social, political and economic consequences.

In this sense, the findings, answers and theses presented in this study are to be understood as:

- developed out of a scientific & practice-related assessment of the situation,
- based on currently established findings,
- overlaid with ideas about the future based on previous experience and
- enriched with visions of the future that have emerged from our own ideas and extensive discussions.



## 4. Digitalisation – general aspects

### 4.1. Areas of impact of digitalisation

The influence of digitalisation is far-reaching. It affects all the companies and stakeholders involved in construction processes as well as the entire lifecycle of buildings.

Thanks to digitalisation it is possible, for the first time, to collect and interconnect all relevant data and to place this at the disposal of all those involved in construction. Hence, this process will have an impact on all partners along the entire value chain of the building, including later users and facility managers.



Plattform 4.0, which was initiated in Austria in 2016 by Goger and Reismann, indicates the areas of impact of digitalisation on the construction industry in its title: Design.Build.Operate, Work.Business.Export.

This title offers us a way of understanding – and managing – digitalisation from the construction industry perspective:

- **Design. Build. Operate**, throughout the entire lifecycle, by addressing such issues as resources, materials, recycling, reprocessing and the raw material cycle
- **Work. Business. Export**, for the sustainable economic success of all, by addressing such issues as jobs, quality of work, job security, business location, business models and export opportunities.

The impact of digitalisation on the construction sector is broad, the interfaces with such specialist areas as automation are fluid and there are intrinsic relationships with many other specialist areas such as construction contracts and the construction industry in general.

In this context, ‘automation’ refers to the transfer of functions within the production process – and, in particular, tasks involving the management and control of processes – from human to artificial systems

A differentiation can be made between:

#### **Mechanisation – level 1**

In which machines only take over the supply of the energy required for the production process.

#### **Mechanisation – level 2**

In which artificial systems and machines take over the functions of the production process.

#### **Automation**

In which artificial systems and machines take over the functions of process management and process control.



This study concentrates on the aspects of work that are specifically related to the execution of building projects. At the same time, however, one cannot ignore the fact that digitalisation will be accompanied by massive social change that will make it impossible to examine such issues in isolation.

Changes driven by globalisation and digitalisation are occurring in parallel. Both politics and society are experiencing clear reactions that are motivated by insecurity and by the fear of developments that are happening too quickly or have been poorly communicated and, in some cases, are clearly undesirable for economic and/or ecological reasons.

## **4.2. Increasing efficiency and productivity**

‘Digitalisation for its own sake’ will not succeed – it must be a means to an end. Market conditions and the customer specifications for a specific project can shape both expectations and requirements. But, at the end of the day, the key forces behind innovation in business are increasing efficiency and productivity. These are the drivers of the growing implementation of digitalisation in companies involved in the construction process.

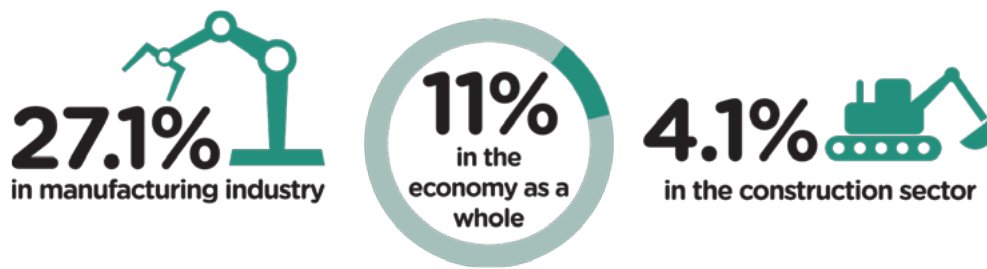
The most concise definition of productivity is “the relationship between input and output”.

*Efficient production refers to a “situation in which it is impossible, given the current resources and technology, to produce more of at least one good and at least as much of every other good. In micro-economic terms this means that the conditions for the least-cost combination have been met.”*

In our own words:

If technological improvement permits higher efficiency we can either produce more goods with the given resources or the same volume of goods with fewer resources.

It is often stated that digitalisation and automation will lead to higher efficiency and, hence, to a rise in productivity. Roland Berger 47 cites the following rates of increasing productivity in Germany over the course of the past ten years:



This means two things

1. The construction sector has an overwhelming need to catch up
2. Higher productivity leads to changes in job numbers.

The study by Roland Berger 47 offers a further example of current conditions and future developments that should lead to an increase in efficiency.

A building worker spends around 30% of his or her working time actually carrying out his or her main activity. He or she spends the other 70% travelling, transporting, cleaning, rearranging or looking for materials or equipment. This suggests a **potential for improvement based on more intelligent site logistics**.

Just-in-time deliveries minimise storage and the need to rearrange material on site. Smart and networked construction machinery makes it possible to optimise the utilisation of machinery and vehicles. A digger uses the Internet of Things to summon an empty truck when it needs one. In turn, the truck asks which material is needed, when and where. Construction workers spend less time on both travel and coordination work; search times and travel distances can be minimised.

Further improvements in efficiency throughout the construction process can be expected from both the digital availability of information and documents and the digital process of exchange and collaboration between the companies involved in putting a construction project together.

#### 4.3. The potential for change offered by digitalisation

Roland Berger 47 offers the following explanation at the beginning of its study “The Potential for Digitalisation in the Building Industry”, dated June 2016,

Digitalisation ... “is changing the role of digital technologies. These are no longer purely supportive tools but will fundamentally change the way in which we do business. And in doing so, digitalisation will affect all areas of companies. It will affect large groups and medium-sized companies, generalists and specialists.”

“A glance at other sectors clearly shows the extent to which digitalisation can turn the most tried-and-tested solutions on their head. In the music industry, for example, the digitally generated share of total turnover is already 46%.”

It is interesting to note that the digital opportunities that are significant for our focus are virtually all classified as “medium-high in terms of influence” or “low-medium in terms of maturity”. This shows us where we are today and what we have to prepare for. (Source: 47 RB Trendradar, diagram page 9).

In other, clear words:

The potential of digitalisation is medium to high – hence, significant.

The implementation of digitalisation is lagging behind – it is emerging and still under development.

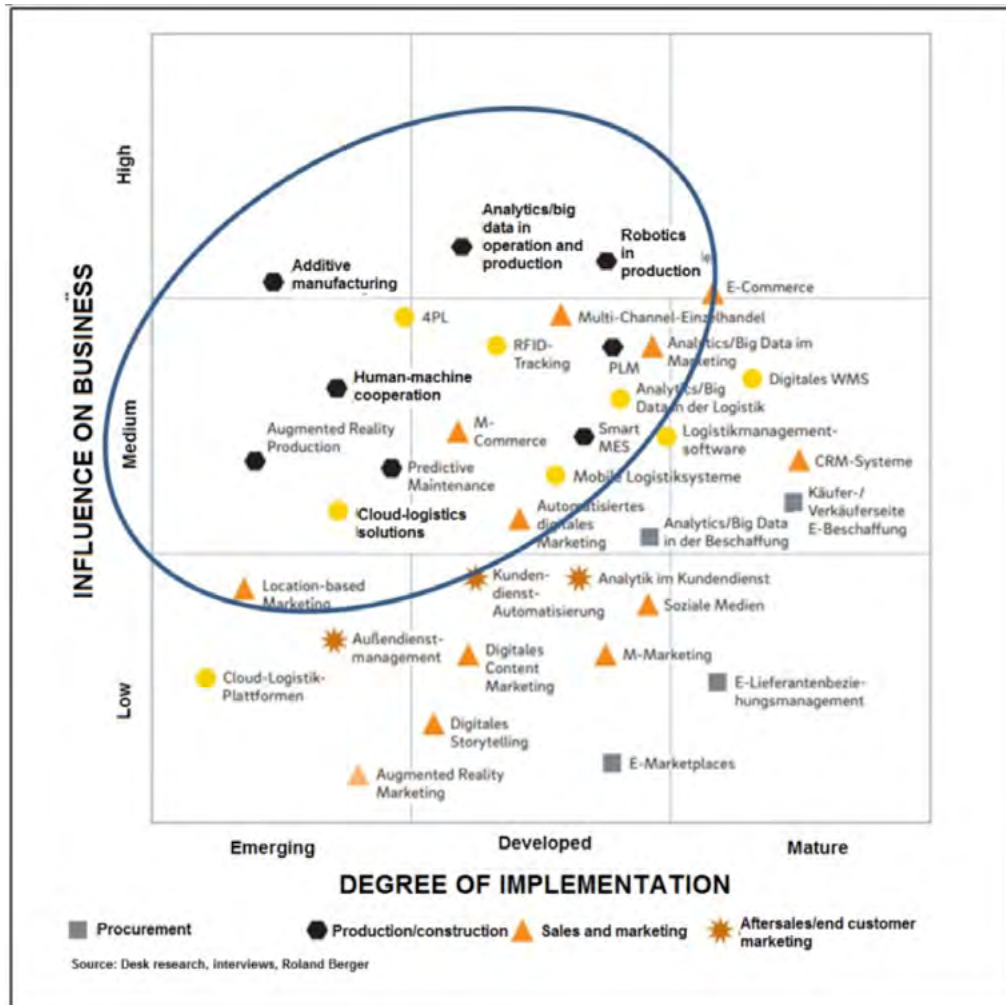


Fig.01 Technology: Degree of implementation and influence on business - Source: Roland Berger 47

#### 4.4. Digitalisation as a disruptive element

The word 'disruption' was adopted from English and its original Latin meaning is more related to the notion of destruction.

As currently used in relation to business and technology, disruption is understood to be

*"... a process in which an existing business model or entire market is superseded as a result of a strongly growing innovation ..."*

And differs from

*"... a normal innovation, which can occur in every sector in terms of how change happens. While a normal innovation refers to an act of renewal that merely develops the market further rather than fundamentally changing it, a disruptive innovation signifies a complete restructuring or even destruction of the existing model."*

According to the dissertation by Sarah Buchner 17 we should expect that, in addition to existing business processes being influenced, new forms of companies will emerge (especially in the 'low end' sector) and new areas of the market will be conquered.

In terms of the construction industry, the current economic influence and level of implementation can be represented as follows:

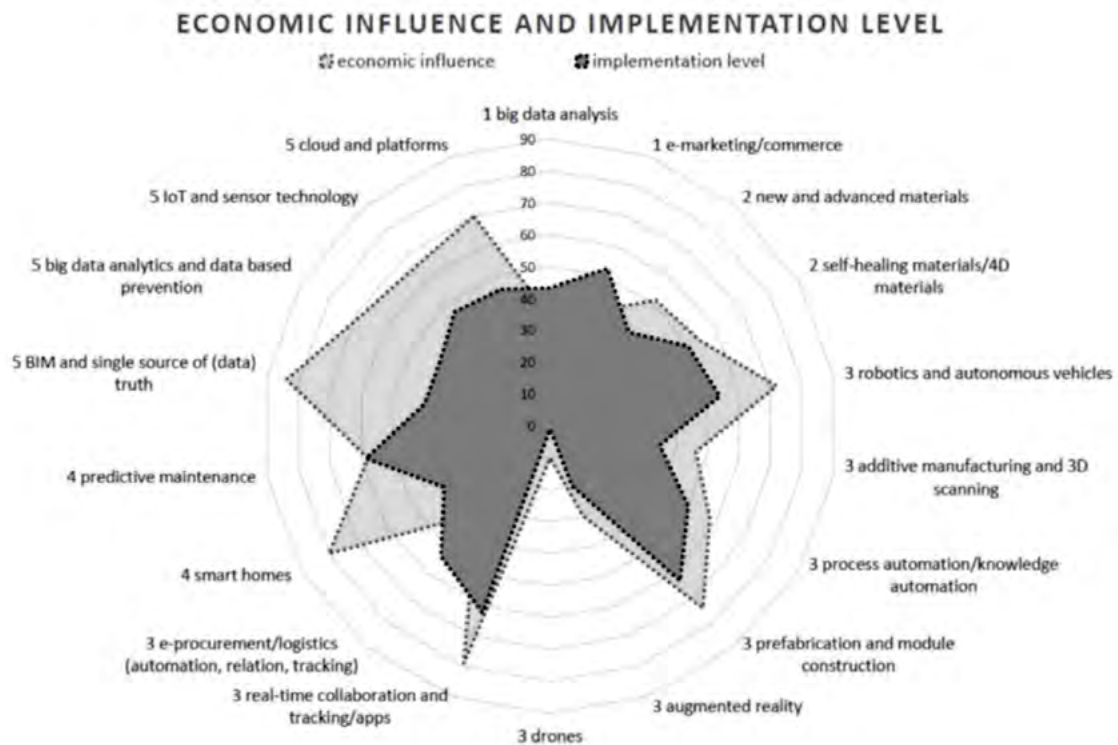


Fig. 02 Economic influence and implementation level - Source: Buchner 17

This diagram enables us to draw the conclusion that the most significant economic effects are being felt in the area of data and in the execution process itself.

The disruption that we attribute to digitalisation also raises political questions. These will be addressed below in Chapter 7 'Society and '.

#### 4.5. Data and information management

Increasing digitalisation is enabling us to capture and produce vast quantities of data.

Firstly, we have to ask ourselves whether we really need this data in this format and what we can do with it.

It opens up potential new functionalities such as big data analysis, 'machine-to-machine-communication' or real-time information about the condition of a building or construction machinery.

But it also brings the risk of creating more work than is necessary for the efficient execution of a project.

In addition to this, we have to be aware that some personal data will be generated, which must be handled sensitively.

In general, it will be essential to determine who has access to which information.

This requires us to address questions of data protection in the context of both personal and company-related data.

However, we must also consider the extent to which data must be accessible – to which project partner and in relationship to which role in the team – in order to guarantee efficient working.

It is theoretically possible to offer every participant in the process – from clients to unskilled workers – access to information that is not relevant to their established role. But this is neither desirable nor expedient: The important thing is to be able to find, evaluate and make use of the decisive information in a targeted way.

A range of technologies (sensors, RFID, etc.) provide real-time information that enables us to react much more quickly, partly with the support of software, to ongoing and unforeseeable situations.



To this end, information must be correspondingly structured and presented in such a way that it is comprehensible and targeted and has the level of detail that is appropriate for each phase of work and that will enable it, upon request, to be used as a basis for decision making.

In the networked, digitalised world one should not forget that data is largely produced ‘for others’: for members of the team within a company’s own workflow, for contractual partners and for other trades and professions, all the way along the value chain to end-users and facility managers.

Those involved in the later stages of the process and other trades and professions must be able to rely upon the validity and reliability of the data supplied to them. This also has legal consequences which have yet to be fully addressed.

Information management will be a central challenge in future – not only for the manager. In order to ensure successful implementation it must be possible to generate information that is captured digitally, stored in a structured way and then supplied in a ‘user-friendly’ and process-focused form.

#### **4.6. The enormous potential of networked data**

Data, data chains and digitalised processes underpin the entire value chain (client, contractor, subcontractor and supplier) throughout the entire lifecycle (designing, building and operation) and support all processes, including fully automated processes.

A key aspect of digitalisation will be the networking of all this data in a way that generates added value. ‘Networking’ means interconnecting this data within the company’s own processes but also, and in particular, interconnecting the data across the borders between disciplines, trades and different contractual partners.

On the one hand, ‘networking’ means that, although the data is recorded and stored just once, it can then be accessed and used on multiple occasions by all subsequent processes and relevant people. This makes it possible to guarantee that participants always work in real time and with up-to-date information. On the other hand, the networking of information enables interdependencies to be identified and made use of at a larger scale, e.g. Big Data Analysis.

The logical networking of data makes it possible to take advantage of enormous potential benefits.

#### **4.7. Digitalisation brings standardisation**

Digitalisation will increase demands for ‘more standardisation’ – but it will also require individualisation. This is not a contradiction.

Standardisation is necessary for the following applications:

- Efficient data management in a diverse software landscape
- Digitalised collaborative workflows to permit the precise coordination of processes
- The digitalisation and automation of specific production and execution tasks

The expected transfer of construction activities from the building site to the production facility and the use of robots will make a particular contribution to increasing standardisation. Modular building will intensify, not simply due to the popularity of ‘prefabricated buildings,’ but in response to a clear demand for repetitive elements which are produced more efficiently and with the required precision and quality. Standardised processes that are carried out under controlled conditions in production halls or by robots on site can be both managed and checked digitally.

This will have an impact on every process – from the identification of options during the architectural design process to the carrying out of repairs by facility managers. Systems must be developed that offer sufficient variability while also taking advantage of all the technical opportunities offered by standardisation.

One should not lose sight of the fact that construction projects are always ‘prototypes’. Individual processes or constructional elements can be standardised but both dynamic architecture in general and the individual parameters of each building project in particular demand that it is possible to carry out the necessary adaptations of every project.

However, it is theoretically possible that digitalisation will permit the high-quality, individual control of machines through the use of production-related information directly taken from the BIM model. In other words it will be possible to make a manufactured product – a building – with a ‘batch size of 1’.

One key aspect of standardisation will be determined by the development of software. This can be illustrated by two extreme scenarios:

- *In the first scenario*, the sector is dominated by powerful software products developed by the ‘big players’ of the IT sector, who seek to perform all necessary tasks within their own software. Even if these software solutions offer the potential for the appropriate level of individualisation for specific companies or projects, the use of such software will also shape processes right across the construction sector. In other words – the software will determine how we work, e.g. SAP.
- *In the second scenario*, a fractured software landscape requires standards for data format at the interfaces between software applications and in data exchange with project partners. Development will be carried out by a multiplicity of software providers and characterised by diversity, a high potential for adaptation in line with special applications and cooperation between software developers and sector-specific companies.

*In addition to increasing efficiency, guaranteeing quality and optimising the use of energy, standardisation and norms should, in particular, create trust and transparency and drive the development of market-ready products while also offering smaller companies speedy access to the digitalised environment. Global and inter-sectoral digital transformation processes require guidelines that give participants the power to act.*

*Freely quoted from 83*



#### 4.8. Transnationalisation through digitalisation

This involves two phenomena:

- The outsourcing of work to other, cheaper regions
- The inflow of cheap labour from other regions

The standardisation process mentioned above opens up the possibility of digitalising and centralising individual working tasks in order to make these location-independent. In this context ‘business process outsourcing’ is often the result.

**Analogy:** The outsourcing of bookkeeping, settlement, call centre and other ‘shared’ services to low-wage economies

Breaking down processes into small-scale, standardised, individual tasks enables companies to use less-qualified workers, as a result of which it is possible to deploy cheaper labour from less developed regions on the building site.

*One example of this is the ‘Dormitory Labour Regime’ introduced by China: Single workers are accommodated in dormitories far from their homes and enjoy little contact with the host country, creating a sense of isolation as a result of which they have a great willingness to work flexible and long hours.*

*Freely quoted from Jörg Flecker 36*

## 5. Digitalisation in building – developments and outlook

### 5.1. An overview

In this chapter, the authors briefly outline the relevant issues in an attempt to create awareness for the broad subject of digitalisation in building. The conclusions of a number of sources are listed below and then drawn together in a summary that represents the current situation as seen by the authors.

The Digital Roadmap Austria, dated December 2016, 42 presents the following features in its Scenario 2025:

- 5G, the new mobile radio standard, together with a well-developed fibre-optic network
- IoT, the Internet of Things, communication by machines with each other and with the Internet
- Big data, new techniques and algorithms for dealing with very large volumes of data
- AI, artificial intelligence and machine learning
- Open knowledge in a range of forms such as ‘crowdsourcing’ and ‘open government’
- VR and AR, virtual and ‘augmented reality’, additional information in real-time
- The use of 3D-printing in the manufacturing process
- Intelligent materials that react autonomously and as required to changing conditions
- Blockchain, data structures that are secure against subsequent manipulation

The “Vision of a Digital Construction Industry” presented in the survey “The Potential of Digitalisation Commissioned by BMVIT and WKÖ” by the Institute for Construction Process Management of Vienna University of Technology dated December 2017 40 describes a series of developments such as:

- Visualisation, simulation and optimisation in the early phases of projects
- Transparency in processes and decisions including stakeholder management
- Open, targeted and comprehensibly recorded documentation via platforms
- Design with BIM, Building Information Modelling, with lifecycle data structure and transfer
- The digitally prepared, supported and organised building site up to the use of drones
- The overall digital administration of the value chain: client-contractor-subcontractor-supplier
- As-built models and CAFM, the use of sensors in building operations
- Urban mining and the digitally captured and controlled material chain

The same study presents the status of technology today in the sense of current applications and evaluates these in terms of (+) what works today and brings benefits and (-) what still has to be worked on, is not yet fully developed and creates extra work today: According to 40 these are

- BIM, Building Information Modelling, in development and design
- ‘Computerised Numerical Control’ in manufacturing, pre-production and production
- Mobile end devices in realisation and execution, e.g. tablets on the building site
- Drones, the use of unmanned flying devices on the building site
- IT in operation and use, CAFM
- Data bases in refurbishment and demolition, building materials

A German study from 2016 by BRZ, Organisation und Bauinformatik 16 (Source interpreted, reference to the Potential Study 40, page 28ff) names six trends that will affect the construction sector and subjects that have to be taken account of and which we address here.

- Mobility, availability of decentralised information and opportunities to intervene (management)
- IT-security, protection against data misuse, data theft and cyber criminality
- Social networks, importance in marketing and informal worker communication

- 'Cloud computing', increasing importance in connection with CDE, data protection concerns
- BIM in design, BIM models in surveys of the existing, continuous data models throughout lifecycle
- Virtual project space, importance in communication, understanding via representation

Once again, the above-mentioned study from Roland Berger 47, as summarised in the Potential Study 40

- BIM
- Digital tenders
- Digital procurement platforms
- Intelligent site logistics ("just-in-time deliveries")
- IoT, communicating machines, RFID
- Drones and robots (3D-laser scanning, construction robots, 3D printing)
- Digitalisation of production by construction industry suppliers (particularly material producers)
- Digital distribution as a direct service

The authors of this study propose the following overview of the key future developments. It is important to underline that the boundaries between these individual subjects are becoming increasingly blurred and that it is not easy to clearly structure and distinguish between them.

The digital world or – 'the virtual reality inside the computer'...

- BIM Building Information Modelling – digital collaboration by project partners in a model
- Digitalisation of ProCS - digital processes for procurement (tender/tender award), contracts, purchasing and remuneration
- Big data – new technologies and algorithms designed to take advantage of the vast quantities of available data
- Ubiquitous and interoperable software solutions - a database-oriented IT landscape in which data can be easily actualised in two directions via interfaces between applications with the increasing help of cloud computing, combined with universal and easily guaranteed accessibility
- The 'Common Virtual Workspace' – digital workflows and communication, within companies but also between project partners, independent of location or contractual relationships
- The 'Digital Twin' – the continuous, joint collection of data during the entire lifecycle of a building in 'virtual reality'

The digital world of the construction site – 'new technologies out on site'...

- 3D-printing: the individually adaptable, controllable via a 3D-model, programmable, production of constructional elements in layers from various basic materials
- Intelligent materials – which are used directly on site or in the prefabrication process and can autonomously react to changes in environmental demands
- Intelligent construction machinery – equipped with sensors that deliver feedback on their status and environmental information and can communicate digitally
- Drones – which offer a speedy, digitalised view of the construction site from above or of areas that are difficult to access
- Robots – the strong, programmable helper who is incapable of becoming bored
- "Powered Exoskeletons" – the reinforcement of the worker's physical strength in the shape of 'motorised muscles'
- 'Artificial Intelligence' - the fast-learning 'brain' of the hardware

Between the worlds – 'Linking the digital world & the actual reality' ...

- 'Mobile end devices' in the realisation process – e.g. tablets and smartphones on site as a means of gaining access to the 'virtual workspace', regardless of location
- 'Augmented reality' – looking at reality from a viewpoint enhanced with additional information from the 'virtual workspace'
- 'Internet of Things' – tools and machines that communicate amongst themselves and document everything
- Sensors in key positions / on materials / in tools and construction machinery – real-time measurement and status information
- Technology for the digital tracking of deliveries and constructional elements (bar/QR code scanners, RFID, etc.)
- Laser scans – measurement and digitalisation of the built reality



- And eventually – the digitalised building: CAFM ('Computer Aided Facility Management'): the building that communicates digitally with users and facility managers

## 5.2. Technological developments

### 5.2.1 Mobility – anytime and everywhere in the Internet

The fact that we can connect with each other in the Internet, wherever we are and whatever the time, has already become a matter of course in our daily lives. The machines with which we do this are constantly becoming smaller and lighter: Whether we use a mobile phone that fits into our coat pocket, a tablet or a laptop is often just a question of habit. Thanks to cloud solutions, storage capacity is no longer an issue and speech recognition is just one of countless operational options.

It is also a matter of course that we expect to enjoy such functionality on the building site – and in some ways this has already arrived.

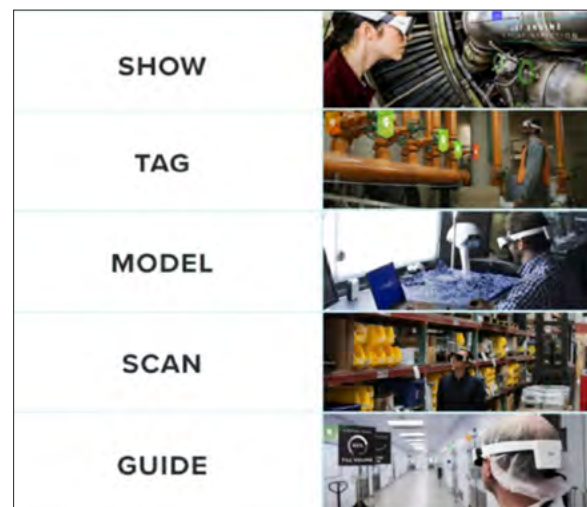
Information is accessible everywhere and, in the same way, we expect to be able to feed it into the virtual workspace at any time, wherever we are: always working with 'real-time information'.

An essential factor for those working on building sites is that they have unbureaucratic, speedy and comprehensive access to information; information, that they could previously only access via cumbersome communication processes, by involving management or by physically 'looking-it-up' themselves.

### 5.2.2 'Augmented reality' – an expanded view of reality

More and more technologies are being used that permit an overlapping between virtual and actual, built reality.

In principle, this process superimposes information from 'virtual reality' on top of the view of actual reality. Examples of such virtual images include projected 3D objects or holograms, text information or the indication of locations for purposes of orientation. The transitions between 'virtual', 'mixed' and 'augmented reality' are fluid. Whether this process requires apps, which operate on tablets or smartphones, or high-tech glasses is currently still a question of hardware and cost. On site, however, these AR glasses have the definite advantage of being 'hands-free' and offer more precision due to their stronger processors and depth sensors. They are controlled by gestures or the movement of the head. One disadvantage, however, of such glasses is their limited field of vision – they offer just 50° compared with the 180° of the human eye.



A further advantage of superimposing the planned world on the built one is 'feature recognition'. In this process, the software scans the reality and compares this with the 3D-model in order to discover which part is being looked at. This means that the identification of a building element requires neither a QR Code nor RFID Technology but is the result of a software-based comparison.

Fig. 03 Applications of augmented reality – Source: BIM Symposium 2019-03: 68

There are many potential uses of this technology and such 'use cases' will become increasingly available on site.

A decisive factor is that data is able to flow in two directions, e.g.: that scans of the 'as-built reality' can be compared with the planned 3D-model and that non-geometrical information (text, images and measurement values) from site can be compared with or added to the BIM model.

Much is expected from the world of research. An example of this – and a source for the above descriptions – is a research project carried out by Vienna University of Technology in cooperation with DAQRI and FCP. (BIM Symposium 2019: BIM auf die Baustelle – Forschungsprojekt mit AR 68)

A special application of great interest to those working on building sites is the use of AR to pass on working instructions: The advantages of AR can be intensified through the use of data glasses because these can enable workers to be directly taught correct manual movements, literally before their very eyes. “Soonish” 82 quotes a study by DAQRI, Boing & Iowa State University that reports on reductions of around 30% in the time taken to carry out an operation and 94% in the error rate even in the case of newly learnt processes.

According to the study “Industrie 4.0 – eine arbeitssoziologische Einschätzung” 33 this argument can be countered by the following:

This method makes the worker even more of an appendage and an executing arm of a computer-controlled process. The task is compartmentalised, no direct cooperation between employees is required and control is reduced to fragmentary instructions and intense monitoring.

On the other hand, the merging of these two worlds in order to facilitate ‘remote-expert’ applications offers speedy support for workers and the potential for learning applications.

### 5.2.3 Robots – the ‘personless’ building site

The words ‘robot’ and ‘robotic’ cover a very wide range – from computer-controlled robotic arms, which can be found in combination with a variety of building machines, to humanoid robots. The interfaces with drones, 3D-printers and standard construction machines are fluid and control mechanisms range from simple integrated computer chips to adaptive AI – ‘Artificial Intelligence’.



Fig.04 Robot-controlled manipulation arm - Source [B.1]

While such technologies have been employed in manufacturing industry for a long time, their use in the construction industry has so far been modest. Robots are particularly suitable for deployment in situations that involve repetitive, parametrisable actions in a controlled environment. It is harder to automate work processes on building sites, which are invariably subject to boundary conditions that have to be considered individually and can always change. In other words, the ‘controlled environment’ of the factory is difficult to replicate on site.

Despite this, however, the use of robots in the construction industry is on the rise:

On the one hand, there is a growth in the transfer of construction activities from building sites to production halls or from the building itself to factory-like prefabricating areas elsewhere on site in which it is possible to create the necessary controlled, standard boundary conditions.

And on the other hand, research is being carried out into the use of robots on building sites and economically justifiable solutions are being developed in partnership with industry. The first, interesting developments are already reaching the market, especially in the areas of 3D-printing and ‘remote-controlled’ or autonomously driven building machinery.

The possibilities of ‘robotics’ are enormous; in principle, every software-controlled robotic arm to which a piece of construction machinery is fixed is already a ‘robotic device’. Developments in this area are occurring very quickly because they involve the creation of hardware and software that can adapt an existing machine rather than the creation of a completely new robot.

There are many possible uses of this technology: such machines can perform hard and repetitive work; robot-controlled glass suction cups can lift heavy panes of glass and position these with great precision – especially in the case of overhead work. If a space permits 3D-flexibility, such robotic arms can be fed with precise coordinates from the 3D-BIM model in order to ensure efficient and correct assembly.

A different solution is being pursued elsewhere, most notably in Japan, where research is being carried out into the use of **humanoid robots**. The construction industry in particular sees this as a means of addressing the current lack of skilled workers.



The flexible robot, which can move in ways based upon human movement, is currently much slower than the human worker but, in compensation for this, extremely precise.

Sources: 45 and 69 (AIST - Japan's National Institute of Advanced Industrial Science and Technology) – freely quoted.

It is possible that, rather than robots, there will be more of a tendency in future towards equipping human workers with intelligent 'exoskeletons', which act like 'portable robots' that enhance both

human muscle power and endurance. One element that can already be found on building sites is the light, motorised metal framework that is worn by the worker and can absorb the loads on certain points of the body such as the hips and transfer these to the ground.

An important piece of the puzzle in the development of such solutions is 'AI – Artificial Intelligence.'

*Research activity in this branch of IT, which is particularly focussed on 'machine learning', is intense. Expectations are high, especially in the field of neuronal methods, which seek to replicate the functionality of the human brain. AI uses algorithms to generate information based on previous experience. The programme acquires knowledge by either recognising patterns in existing data sets or by observing processes. In*

*the field of 'machine learning', AI can turn to all possible external sources of information – from sensors to big data. This also means that AI can develop autarkically.*

*70 - quoted freely.*

In principle, AI can be implanted into any machine as a form of artificial brain – the range of possible uses is very broad, from augmented reality to humanoid robots. This means that self-learning robots can also be increasingly employed to carry out cognitive, non-routine work.

Despite this, however, it is to be expected that human work will only be replaced by robots in certain ways. It will be a considerable time before AI can take over tasks that involve the rapid understanding of complex interrelationships, tasks that require significant amounts of creative intelligence or tasks in situations that demand social intelligence.

The most likely scenario for the building site is that people and robots will work together. Robots should support human labour by taking over tasks that are either routine or require particular strength or precision. But robots will always have to be operated by people.

In the most extreme form of this scenario a worker will remotely operate a number of robots or machines equipped with artificial intelligence.

*Kajima has started tests in which personless and GPS-equipped trucks, bulldozers and road rollers are deployed on building sites. This enables one worker to control five different pre-programmed vehicles as they carry out a range of tasks, such as unloading earth and compressing and then smoothing the ground. This would increase labour productivity per (human) capita and even make it possible to replace workers. The company not only wants to use these machines itself but also intends to be able to sell them to other construction companies.*

*From 69*

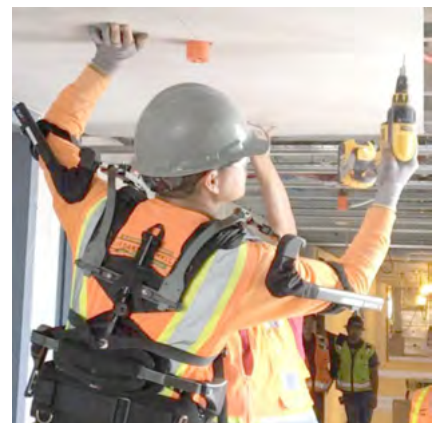


Fig. 06: A shoulder unit absorbs the load, allowing the worker to concentrate on manipulating the tool - Source [B.3]



But in order to remain both productive and profitable, the cost of altering the programming must be minimised. This means that there will be a long transition phase in which people are retained to manage the machines – even on site.

The emergence of 'Industry 4.0' and CIM (Computer – Integrated – Manufacturing) has been accompanied by numerous predictions about the 'personless factory'. Developments on the ground, however, show that the expected radical results have yet to be achieved. In a similar way, the 'personless building site' should not be expected in the near future. Indeed, we should carefully consider the extent to which such a scenario is at all sensible or desirable.

#### 5.2.4 3D-printers – the printed building

Any computer-controlled and automatic process in which material is applied additively or in layers can generally be referred to as 3D-printing. The great advantage of such processes is that they offer complete flexibility in terms of form, as long as this form is compatible with the chosen material and the basic principles of structural engineering.

Developments have been rapid in the past few years – from small plastic elements made by a box-sized printer to the robot-controlled production of directly deployable building components.

Almost every material can be 'printed': concrete, bricks, plastic and metal. In principle, this requires a robotic arm that can be flexibly programmed and a 'delivery system' for the required material. The process is limited by the mobility of the robotic arm and the time required for the material to harden before the application of the next layer.

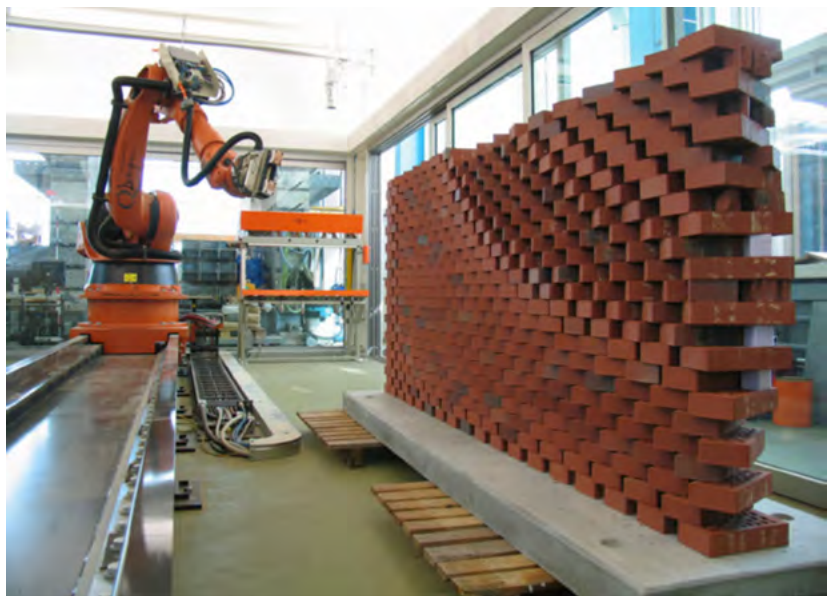


Fig. 07 A robot building a brick wall with a complex geometry - Source [B.4]

3D-printing for construction activities is an active area of research and ETH Zurich and TU Dresden are just some of the institutions leading the way in this field.

It will, however, be some time before such technology can be employed commercially. Projects of cooperation with the construction industry (e.g. Wienerberger Hadrian X, SAM from Construction Robotics) are working intensively on the development of implementable solutions.

Further industrial applications include: Voxeljet Züblin 3D-printer: your 3D manufacturing

Or, according to Roland Berger 47:

... 3D-printer. A company from China already uses this technology: This company prints building parts made from a mixture of fast-drying cement, industrial waste, building rubble and glass on the basis of the 3D-building plan. The printing process for a three-storey house lasts two days. This reduces the construction time by up to 70% and the required labour by up to 80%. In addition to this, there are savings in material of up to 60%. Because there is hardly any waste and, indeed, other waste is recycled, the process also protects the environment. For a large contract in Egypt for more than 20,000 buildings the Chinese company is to use a sand-based printing mixture. Hence, the innovation takes regional characteristics into consideration, which further increases efficiency.

In the construction of single-family houses, the demand for individuality will probably prevail: It is not technology but people who make the difference. However: 'printing rather than cutting' or 'printing rather than pouring' will soon be an economically interesting alternative in at least some areas of the building industry.



### 5.2.5 Tracking – everything can be followed

The ‘tracking’ of building components, people and machines offers great potential for making the building process more efficient.

On the one hand, this involves tracking building components with certainty on their journey from the producer or manufacturer to the place where they will be installed on site.

This requires the component to have an explicit, digital ID. This can be a barcode or a QR code which is attached to the component and manually scanned or can be carried out using a dedicated hardware scanner or apps, which operate on smartphones or tablets.

In order to use RFID technology components must be equipped with the appropriate chips, which contain the ID of the component. ‘RFID’ (‘Radio-Frequency Identification’) is a technology that employs radio waves for purposes of contactless identification and localisation. These high-frequency radio waves are produced by a reader that uses them to locate and identify the ‘transponder’ on the component, which is equipped with an antenna. ‘Active’ transponders that can generate their own power can be used in order to extend the range. The ID and position data permits additional, component-related information to be transmitted.

The availability of mobile devices with greater computing capacity means that form-based recognition – ‘Feature—Identification’ – could also become possible.

Localisation essentially refers to the ‘asset tracking’ of construction machinery. GPS-tracking units in construction machines both permit localisation and also, with the support of the appropriate software, enable the displacement of machines to be controlled and their radius of movement to be restricted. Construction machinery equipped in this way cannot leave defined, virtual ‘GEO zones’ (‘geofencing’). This feature enables operators to monitor the area of deployment of machinery while also acting as a form of anti-theft prevention.

It is also conceivable that blockchain technologies from the field of transport logistics will be used in the future.

### 5.2.6 Drones – everything can be seen

First and foremost, the use of drones can save a lot of time and money in the inspection of structures that are difficult to access such as bridges and towers.

The determining factor behind the use of drones is the ability to equip these flexible, unpiloted flying machines with additional technologies (e.g. laser scanning) that permit the digital recording of the building site.

The comparison between these recordings of the actual situation on site and the digital 3D-model enables a range of digital evaluations to be carried out:

- automatic recording of progress
- automatic quality checks
- digitally supported acceptance procedure
- digitally supported invoicing procedure

### 5.2.7 Sensors - everything can be measured

(Almost) everything can be measured:

- environmental conditions
- generated forces or deformation
- information about the condition of a building component or the operational status of machinery
- user requirements

Sensor-based measurement provides no more than a basis for analysis and decision-making.

Enhanced by comparative information, data analysis, modelling and calculations these sensors can enable largely independent processes to run in the background and then work in combination with up-to-date project data to offer visual aids to decision-making or even react autarkically as a means of establishing even larger control loops.

The potential uses of sensors are unbelievably diverse. They can be found in 'smart workwear' and all machines and can also provide information about the condition of building materials or building components during the construction process (e.g. concrete strength or deformation).

Completed building components that are equipped with sensors deliver information that can be employed by users and facility managers. This technology also permits components to be individually adapted to meet client needs.

*Sensors are particularly widely used in building machinery. Automatic messages notify about maintenance requirements, increase reliability and minimise breakdowns. Combined with technologies such as high-definition cameras or lidar ('Light Detection and Ranging') machines can even be remote-controlled: In this system, distances and speeds are optically measured by laser beams – in a similar way to radar.*

*Freely quoted from: <https://de.wikipedia.org/wiki/Lidar>*

The increased efficiency and energy optimisation expected by construction companies and building operators will ensure that the use of sensors will continue to grow – and this will have direct consequences for building workers. Sensors will help operators of machinery to operate it optimally. In extreme cases, however, they will also replace them. Not only can workers who operate these machines or move around with them be localised at all times, but their performance can also be recorded; this also raises the possibility of generating personal data that must be handled sensitively.

### 5.2.8 'The Internet of Things' – do we still have a say at all?

'Internet of Things – IoT' is a collective term for all the technologies that enable physical and virtual things to network with each other.

Another term used in this connection is 'cyber-physical system'

*...a combination of IT and software-related components and mechanical and electronic elements that communicate via a data infrastructure such as the Internet.*

*From 85*

As long as they have a reliable Internet connection, 'intelligent' machines will be able to communicate in future in 'M2M - machine to machine – communication' (without the involvement of humans). In the subsequent development phase, communicating machines will reach decisions themselves on the basis of situations assessed by sensors combined with information from the virtual workspace. This will pave the way for automated self-control.

In the area of construction machinery, this will lead to more and more driverless systems. In the near future, it is quite conceivable that we will see the extensive use of largely autonomous construction machines, which are equipped with appropriate technologies such as high-definition cameras or lidar, steered by AI and in permanent contact with other AIs.

## 5.3. Digital collaboration

### 5.3.1 The challenges of digital cooperation

A key element of building projects in the future will be cooperative project work that is digitally supported and/or performed in an underlying common data environment.

The buzzword 'BIM' has been on everyone's lips in recent years and is seen as the embodiment of digital collaboration. But digitalisation means much more. It opens up new opportunities for cooperation – across departmental barriers within a company but also beyond contractual boundaries – largely due to the way in which it makes all possible information available in the form of interconnected databases

'Digital collaboration' – exchanging data and working together within a single model, a 'virtual reality' twin that can be used for the entire lifecycle of a building – will become a central challenge.

The expected and hoped-for impact will include:

- higher quality of design, of both the process and the building,
- higher quality of execution along the entire value chain,
- lower lead-in and processing times.

However, collaboration requires the appropriate mindset:

*The greatest difficulty is and will remain the development of a shared, interdisciplinary understanding of the needs of other project participants. Working together within a model requires new ways of thinking about relationships, hierarchies and processes: And while the mutual interdependencies and interweaving of processes and interfaces change nothing in principle these will become much more significant and require detailed organisation. All professions, both designers and executors, will have to learn to accept more transparency and approach their roles and responsibility with vision: More than anything else this is a cultural issue.*

From 14

### The Common Virtual Workspace

Digital cooperation in all design, execution and operational processes requires the fulfilment of a comprehensive series of requirements.

The solution must facilitate not only all aspects of the technical design of the object, but also the entire digitalisation of costs and timetable management, the recording of status, resource planning, and document management, etc. – as well as the digitalisation of all communications processes that are essential for common workflows and coordination.

This requires the creation of a virtual space in which information can be stored and made accessible and to which all partners and every current member of the team can have access.

This space has a range of possible names: virtual project space / virtual workspace, digital workspace, project platform and common data environment, etc.

On the surface, these spaces are digital platforms that enable workflows to be introduced and various 'access levels' for access to data to be created.

'Below this', information is stored in databases. By interconnecting these databases and equipping them with open interfaces with expert software the comprehensive, virtual workspace is complete.

A simplified overall image of the architecture of the virtual project space with central databases could be as follows:



Fig. 08: Central databases in the project space - Source 14 "BIM im Metallbau"

If the resulting, digital workspace for a specific project is made accessible to a range of participants this creates a 'Common Virtual Workspace'.

All necessary information regarding the digital cooperation is then stored in this digital space – 'workflows' also take place here and are accessible as 'historic' data.



Hence, this space is home to:

- **Plan information**, which is subject to a permanent process of adaptation in line with all outputs and alterations, both within the production process and on site (3D / 4D / 5D)
- **Actual information**, which is fed in on the basis of the built reality and all processes connected with the construction (information about the building project, environment, equipment, workers, etc.)
- **Digital collaboration**: exchange of information / communication between all partners involved in the construction (workflows / documents)

All project partners have the degree of access required by their scope of work.

These spaces have different levels for clients / construction companies / subcontractors as well as 'protected areas' for individual use.

The result is a '**Single Source of Truth**', which facilitates efficient data retention but also influences the entire process of change and claims management – as long as the information is digitally captured and stored historically in a way that makes it hard to manipulate.

Some processes have already involved database-based applications for a long time. These include ERP software products such as SAP and collaborative document management programmes such as Aconex, which have become well-established on the market. Share-point solutions can be individually drawn up by companies themselves.

The important factor here is not 'uniform software' but central data retention. Special software will always be required for special applications (e.g. structural calculations). The adaptation of workflows for individual projects will lead to higher efficiency.

Another decisive feature is that the same data material is always accessed and that this only has to be saved once.



This process will not make cooperation 'simpler'. A reduction in complexity should be expected on neither the operational nor the project level. Indeed, the opposite will tend to occur because, firstly, inter-departmental communication within a company was already complex enough and, secondly, the inclusion of further participants from along the entire value chain (clients, subcontractors and other trades or professions) will probably make it even more of a challenge.

There are also countless IT-related challenges, from the interoperability of the software applications to the need for a high-performance Internet access – everywhere and all the time – and flexible storage concepts such as cloud computing.

*"Cloud computing is the approach of providing central IT infrastructures, platforms and software and connecting these as required with the end-user via a network. Centralised data storage and processing offers potential savings compared with local storage by the user but also raises a series of security questions. On the one hand, there are warnings of a loss of control over one's own data and, on the other hand, an increase in security demands due to the central availability of information."*

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### 5.3.2 Planning together – BIM

BIM is short for 'Building Information Modelling' or 'Building Integrated Modelling'.

This refers to a digital 3D-model – a 'digital twin' – of a built object that is, in turn, a collection of individual three-dimensional objects. These objects can be graphically controlled using the appropriate software and enhanced with information.

In order to create a comprehensive model of a built object it is essential that the entire planning team of architects, engineers and other specialist planners works on this model in a shared data space. This means that a BIM model is a collective work.

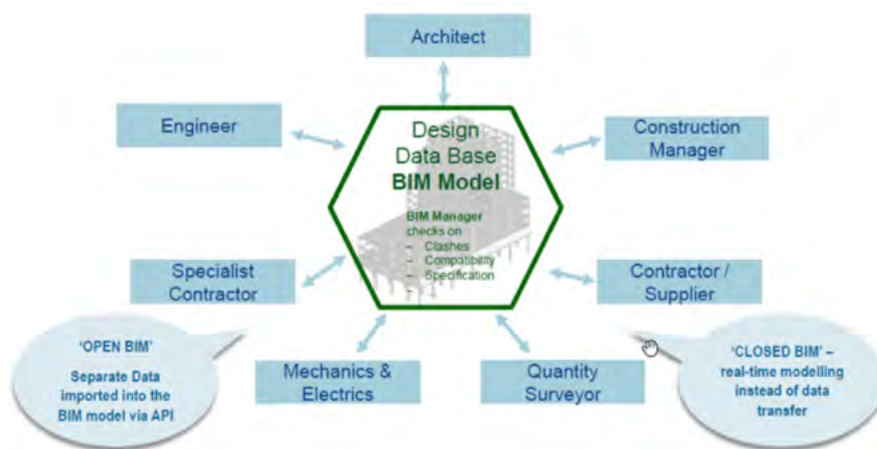


Fig. 09 BIM – Working together on a model - Source 14 "BIM im Metallbau"

There is a fundamental distinction between two basic types of BIM: If all planners involved in a project are working in the same model one speaks of "Closed BIM". The so-called "Open BIM" way of operating describes working with a range of software and then combining all the resulting data in a coordination model.

In both the above cases the digital model becomes the central common information medium. In addition to being a spatial representation it contains additional information such as material and technical specifications, etc., which are assigned to the individual objects. Building components can also be assigned time-related information – e.g. related to production, delivery or installation – under the motto '4D-BIM'. This permits the comprehensible visualisation of the building over time, which, in turn, makes it easier to plan the construction process. A 3D-model permits highly effective scenario planning. Such issues as accessibility in the event of complex phases of assembly or the coordination of simultaneous processes can be checked (both within and between trades and professions).

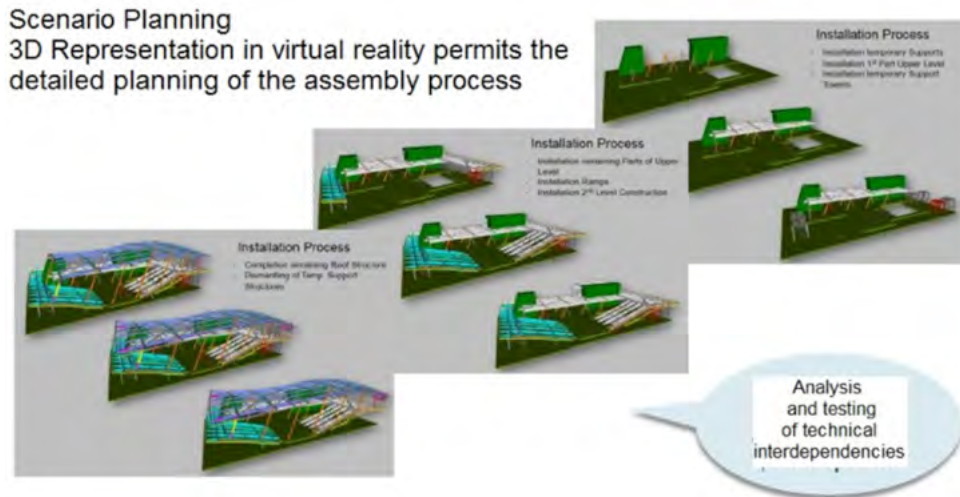


Fig. 10: Planning of the construction process in 'virtual reality' - Source 14 "BIM im Metallbau"

If cost information is also assigned to the elements then the digital model can also be used for the cost planning, calculation and settlement processes – in other words, as '5D BIM'.

'6D BIM' refers to the management of data in the model during the use phase of the building: Operationally relevant information such as maintenance and cleaning intervals or manufacturer-specific information can be collected in the digital model and placed at the disposal of the facility manager.

The construction of such jointly used models also places new demands on the quality of the digital information. As long as there is a lack of adequate standards, this data quality has to be defined on a case-by-case basis. This definition is laid down in contractual documents such as the Employer's Information Requirements (EIR) and the BIM Execution Plan (BEP)

*The operational design of the contract includes the contract, the BIM-related special contract terms and conditions, the specifications for the BIM-based planning work and the BIM specifications. The Employer's Information requirements (EIR) are part of the tender and determine the BIM objectives and BIM use cases in each project. The BIM Execution Plan (sometimes described as the BIM Rulebook) determines the technical rules and standards for the project development. This includes not only the necessary roles, functions and processes but also the technologies, interfaces and interactions that are to be used by and between the project participants (model structure, tolerances, hardware and software, data formats etc.). The BIM-related special contract terms and conditions determine the legal requirements of the project development. Typical contents include the organisation of data exchange, the role and responsibilities of the BIM manager, rules covering data sovereignty, ownership and copyright. The BIM specifications establish the technical and organisational parameters for the day-to-day work on the building data model. This typically contains information about the chosen software, data storage, modelling rules and revision tracking, etc.*

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### 5.3.3 Joint processing – the digitalisation of ordering and delivery

The comprehensive digitalisation of the value creation process includes all data chains related to ordering and delivery. This can include processes at both the project and the corporate level but also involves developments in the field of e-commerce such as specialised online trading platforms for construction-related products and services.

The objective within construction projects will be to digitalise and, hence, to optimise all contractual and commercial aspects of the ordering process and the operational cooperation with suppliers.

A key aspect of this will be logistics and the traceability of deliveries. ERP software has already been used successfully for this purpose for many years. A decisive factor will once again be the quality of the interaction and collaboration with other processes and companies. As so often, the forerunner of the construction industry in this area is the automotive industry. Parts suppliers have been phenomenally closely integrated into the car production process for decades.

In order to permit a suitable level of traceability it is essential that every component is digitally identifiable – e.g. tagged – from design to final settlement. In order to achieve consistency, this digital ‘ID’ should be used by all participants.

This will enable information about construction components to be retrieved during their entire lifecycle that will make the production and delivery process easy to follow and, hence, more ‘manageable’. As a result, every stage in the life of a building component up to the acceptance of the built object and even into the use phase can be traced.



In order to be able to organise the exchange of information on jointly operated platforms, suppliers will be required to demonstrate a certain level of transparency. This indispensable permeability will naturally also require aspects of data protection such as trade and operating secrets to be taken into account. But the most important requirement is the right mindset: an openness to the notion of sharing information rather than a reliance upon withholding it as a means of playing tactical games.

### 5.3.4 The digital building site

The digital purchasing process is of course closely linked with the workflow on the building site.

The digital ID of building components means that it is reasonably easy to gain status information on site. Relevant, progress-related information about such issues as

- arrival on site
- the ‘handling of materials’ on site
- integration into the building
- quality-related processes and
- completion and acceptance

can be captured and made accessible to all relevant project partners.

If associated plan information is also fed into the model the digitally-controlled permanent comparison of CURRENT and TARGET data can be carried out automatically. The progress of the execution can then be visualised on the 3D-model and presented in an easily comprehensible form.

In addition to this, the ‘digital building site’ can also be seen as a comprehensive pool of information and a digital working platform for all elements of the entire building execution process, which should also be placed at the disposal of all relevant project participants.

The ‘digital building site’ is often understood to be a ‘paperless’ building site – however, the digitalisation of documents is just a first step, which has already been largely completed during the course of the past few decades. The next steps are the digital recording of information, the provision of this in a database and the overall analysis of this information. This means that comprehensive networked information will be available to all participants on site but also makes it essential that this information is permanently updated and adapted by all members of the team.

This essentially includes the following elements:

- the 3D-model of the building project including technical specifications about all parts of the building
- logistical information about the supplied parts including their storage on site
- invoicing and ordering information (regarding the client and other contractual partners)
- equipment and machinery data (including current measurement information from sensors)
- personnel management information regarding the site personnel
- data about weather and other, partly local, “environmental conditions” in the working areas
- information about the progress of the building project

- the status of the acceptance process for the individual parts of the building with detailed information regarding quality, including the processing of 'non-conformity reports' (snagging)
- timetable (events from the past and naturally detailed plan information)
- the site journal, which is of course now only available in digital form.

### The building in 'virtual reality'

It is becoming increasingly clear that a comprehensive 3D model of the building brings advantages to all the participants in the building process and, in addition to this, can also be used by later operators and facility managers and as a basis for 'predictive maintenance'.

This means that the BIM model can support not only the joint development and detailing of this model in the design phase but also the transformation of the planned building into built reality. Following the completion of the building, all the information required for the use phase will be available and can also be accessed via the 3D-model in an easily comprehensible form.

Hence, the production of a 3D-model of the building in 'virtual reality' that is enhanced with information that can be used by all project participants is becoming a basic requirement

*Developers, investors, clients, architects, engineers, specialist planners, statutory authorities, executing companies, users, visitors and operators – they all want to reap the benefits of the creation of this virtual building.*

*From 14*

The process of 'building' is thus increasingly taking place in two parallel universes; a digital twin – which can actually be seen as an 'add-on product' of the building process – is emerging alongside the built reality.



Fig. 11: Technical and 'historical' information about the building and its components are available in 'virtual reality' in the form of a 'digital twin' - Source 14 "BIM im Metallbau"

However, in order to create such a comprehensive copy in virtual reality, information must be regularly updated and added from the very first design stage.

This virtual copy 'lives', just like the actual building. All the participants in the building process make their contribution. It is particularly important that changes during the execution phase are incorporated into the 'digital twin' because, in order to be a real 'twin,' it is essential that it is identical to the built model.

## 5.4. Visions of digitalised, automated working processes

### 5.4.1 General

The authors illustrate this subject from three types of sources:

- from the literature, by summarising the relevant sources currently available to the authors



- from their own experience and reflections, in the form of critical appraisal and creative vision
- from interviews and conversations with experienced experts

The authors are well aware that these sources involve subjective projections into the future or, in other words, hypotheses, which are not substantial enough to be either proved or disproved from today's perspective. But how should one anticipate the future otherwise?

The terms used have simply been selected on the basis of comprehensibility and will occasionally deviate from the standard. This is intentional, as are all the other simplifications that have been made in order to ensure that the following scenarios remain comprehensible. Whether the mentioned software or hardware is already implementable or even conceivable today is deliberately overlooked in this chapter. The authors are developing visions in order to understand areas of investigation and develop recommendations for action.

These visions are also regularly interspersed with analogies – examples that show the speed with which digitalisation has been and is being accepted and integrated into some areas of daily life. These should make it easier to envisage some of these changes.

These observations also take fully into account the sometimes different requirements of the building sector.

No one can clearly say whether these or similar scenarios will occur, occur in a completely different way, or not occur at all in five or ten years. However, we need scenarios if we are to illustrate potential developments and recommendations for action with some degree of clarity.

#### 5.4.2 The major international building site of the future

Let us imagine a future major international building site for a complex building ....

The following description will focus on the situations of the supervisor, the foreperson and the labourer (S/F/L).

##### At the entrance to the site

A typical working day: There was nothing unexpected in the employer's daily message to the worker's 'personal mobile device'. The weather is mild for late winter – as predicted by the now very reliable weather apps.

The S/F/L was already registered upon starting work for the first time. All his or her data was recorded in the site-specific database and synchronised with the trans-regional employee database. This recorded data includes information about work permits and company affiliations as well as all the information relevant to the employment contract.

But personal data such as nationality, age, languages, the necessary, regular health checks, criminal record and personal 'health & safety track record', etc. have also all been recorded.

Of course this recording of personal data requires the consent of the individual concerned – but this consent is also a condition for being able to enter the site.

Not only the individual workers but also all the contractors and subcontractors represented on site are also registered in this completely transparent way.

Following the normal security checks, a final identity scan enables the worker to pass through the access barrier. As soon as the worker is on site, his or her 'movements' are electronically recorded.

**Note:** International experience shows that, for example, an iris scan is more reliable than a finger scan or electronic access card. The aggregation of 'plastic cards' for every possible purpose will cease. Whether implanted chips establish themselves has yet to be seen. In any case, each worker will have a 'digital ID' as a result of which it will always be possible to locate them.



## First steps

There are various possibilities for the next step:

The labourer goes to the changing room where he or she changes into their site clothing.

This clothing is equipped with sensors that enable it to adapt to the environmental conditions. Such 'smart textiles' make it easier to work in different weathers and climatic zones. The standard site equipment includes a 'hard hat', which contains the hardware for 'augmented reality' and, naturally, also a pair of augmented reality glasses.



The working language on the major international building site of the future is, naturally, English, but a 'Babel Fish' – a small simultaneous translator – can be inserted into the ear in order to overcome linguistic barriers when complicated instructions are to be passed on to the international labour crew.

**Note:** The increasing availability of written instructions means that language will become a less significant barrier: Translations can simply be generated from the Internet. Images / films / simulations can also pass on information effectively to labourers with less specialist knowledge.

The supervisor and foreperson start their day in the control room. There is still no food printer so their first steps lead them to the conventional coffee machine (although the cups come from the 3D-printer and largely consist of recycled material from old cups.)

## The control room as a central workplace

A key element of the control room is the 'screen wall' upon which all the information from the 'common virtual workspace' can be displayed.

**Note:** The development of the screen represents a significant success factor for the realisation of this scenario.

The S/F/L can obtain a general overview from the screen in the site hut or control room.

All possible mobile devices can offer their user access to the necessary information but it is this large screen wall in the control room that provides the essential overview.

It is here that information about the exact progress on site can be gathered quickly – and visualised in the 3D model. This model shows the detailed status of ongoing individual constructional tasks in an easily comprehensible way. Simulations of complex assembly situations can also be shown.

It is essential that all information comes from the same pool of data – the 'common virtual workspace' which is the 'single source of truth'.

First of all, the S/F obtains an overview of the progress made by the night shift (visualised graphically or colour-coded on the 3D-model).

This information comes directly from the database, which is fed by the fully automatic building component tracking system. Plan information is permanently updated on the basis of ongoing events.

The first action of the day is to call up the planned to-do list and discuss any uncertainties together. The site manager and supervisors can still exchange ideas at this 'morning meeting', but all the key detailed elements of the planning for that day, such as the detailed daily schedule, working instructions for individual tasks, equipment requirements with operational information and a list of required material indicating delivery and quality status, etc. are available digitally.

**Note:** Even if there is a meeting every day in which the instructions of the site manager and supervisor are presented to the team, the S/F/L are still able to download the necessary instructions about all planned work themselves. However, meetings will remain essential as a means of exchanging ideas. Despite or perhaps even

as a result of the multitude of digitally available information it is necessary to create opportunities to communicate directly in order to fully discuss ambiguities.

The exchange of information – including with other stakeholders and with the client, etc. – will increasingly take place in digital space. However, communication – in the sense of sharing ideas, clarifying, agreeing, negotiating – will still demand direct contact.

The next step is to check the availability of all required materials. The list of materials including small parts and the associated equipment is downloaded by the foreperson from the Internet and a comparison with the current status of the delivered parts from the database shows whether all the elements included in the planning for that day are available.

Gaps in the list of material that is required in the coming days are then discussed with the supervisor. If something is missing the supervisor will ensure that an ‘early warning’ is entered into the project workflow and sent to the logistics team.

### **The continuous digital tracking of all delivered materials**

The first external event occurs: a delivery is planned for 9:00. The transport note includes all up-to-date traffic information, which enables the arrival of the truck on site to be coordinated with all other transport activities.

The truck passes through the gate, which scans and records the ID of the truck and all the people and products that it is carrying and records this information in the database. All necessary approvals are checked digitally – the truck is cleared to enter the site and is guided by apps (machine-to-machine communication) to a predetermined position. The truck is unloaded by robots – forklifts and mobile cranes controlled from the control room.



The delivery process is, naturally, just-in-time and coordinated with the execution process and current construction timetable. This considerably reduces the requirement for storage space on site, which is a crucial advantage in this downtown location. This is also made possible by the fact that the delivery chains are precisely coordinated and correspondingly controlled by a specialist team.

On site, every delivered item is covered by automatic location recognition (via microchip or RFID). This enables the position of every single component to be retrieved at any time from the database and visualised on the digital site plan. ‘Mobile devices’ also make this information accessible to the S/F/L – in real time.

Even small parts are digitally recorded and available in sufficient quantities at any time.

(A further advantage of this is that it provides a certain level of security against theft).

**Note:** There is a general expectation that the production process will increasingly shift from the building site to some form of prefabrication under controlled conditions. If sufficient space is available it is conceivable that this prefabrication could take place on site. The construction process itself will involve an increasing amount of work that is little more than the ‘assembling’ of modular units.

### **Information on the building site – from tablets & smartphones to augmented reality**

After the supervisor has obtained an overview from the screen in the control room he or she goes out onto the building site. Internet access is naturally guaranteed for everyone, everywhere on site, and functions reliably, even in sealed off parts of the building.

All necessary information is available via mobile devices such as tablets and smartphones to the supervisor, foreperson and also, to the necessary extent, to the labourer. This is ‘real-time’ information, which means that it is updated constantly.

**Note:** The S/F/L can also retrieve – from the ‘Common Virtual Workspace’ – all the information required to carry out their work at a scale that previously only available to managers. This direct availability of so much information also means that decisions that previously required the involvement of management can now be taken by site personnel or, at least, that all possibilities and suggestions can be clarified in advance.

A decisive factor here is the processing of information: 'Smart apps' enable information to be directly prepared to meet the needs of each individual task.

As the supervisor takes his or her first tour of the site it is helpful that all detailed information related to any specific building component can be accessed via the AR glasses. The supervisor can search for and manage this information on the glasses with the help of small control elements in their work gloves.

**Analogy:** The transition from the folded map to the speaking navigation system in the car or the GPS on the mobile phone has been fully accepted by everyone in recent years. It is only a small step before this information is shown on the windscreen.

**Note:** The 'paperless office' and/or the 'paperless building site' are seen by many as the epitome of digitalisation. Of course this vision only represents a small selection of all the possibilities offered by universal digitalisation, but the transition from studying plans to 'looking inside a 3D-model' is already seen by many of today's site personnel as a major challenge. They fear losing the sense of overview and the ability to rapidly capture information and make notes offered by the medium of the paper plan.

The tracking of the progress of construction and quality by the S/F/L

On his or her tour of the site the supervisor notices certain information regarding the progress of work that requires completion or amendment and they directly modify this information in the database via apps on their tablet while also synchronising this with further related individual tasks or correction measures.

'Mobile devices' offer the S/F/L permanent access to information while also enabling them to feed current status-related information into the 'common virtual workspace'.

Each supervisor is responsible for recording progress. The automatic project management programme, which has been prepared in advance, specifies to the day and to the hour when each individual task should be performed. As these individual tasks are completed the foreperson – partly supported by the labourer – records this progress in parallel via special apps on their mobile devices.

In this process it is important that each individual building component has an electronic ID in the form of a label with either a printed barcode or a QR code, dependent upon the supplier. From the point of view of the building site, microchips are naturally preferred because these can be read by RFID technology rather than by scanners as a result of which they can contain all the information associated with an individual task.

The apps used for recording progress were coordinated directly with each individual task by the contractor's internal IT team before the start of work.

Today everything is going to plan and no additional input is required. The good, joint preparatory work has paid off. The first phases were more difficult and detailed adjustments were often required.

The app is now well-aligned with the requirements of the project: e.g. in the event of deviations from a standard menu the type of deviation can be found and, if necessary, described with the help of photographs, short texts and voice input. The input menus are standardised and adapted to the requirements of the project to such an extent that these can now also be directly operated by every labourer and, if necessary, by a foreperson.

Drones are also available for large areas or areas that are difficult to access. To date, however, these have only been required to check the top of the atrium, which is difficult to access and where there is a complicated interface with the roof that is being executed by a different company.

The recorded data is also used for subsequent processes (automatic reporting of the progress of work, all recording of defects, automated administration and





payment) and is accessible to not only the executing company but also the client, the project manager and the 'third-party quality controller'.

Of course not everyone can see 'everything' – the access to data is controlled by several 'levels of transparency' and only the information essential to any required cooperation is shared. The contractual regulation of the visibility of data is an important element of the collaboration agreement, the relevant parts of which were presented to the site team in the start workshop by the contract manager.

This means that precise work is required – otherwise there is a profusion of annoying questions and additional checks.

The site team is particularly happy about the fact that the apps are simple to operate. In order to achieve this, the company's own expert spent several weeks on site adjusting them. In the meantime this work has also paid for itself. The clearly structured and easily operable app has already saved a lot of time in terms of following up the quality status of the project and any repair measures.

**Note:** Flexibility and user-friendliness are significant aspects of the apps that are used. Very close cooperation between the development team and the experienced people on the building site pays dividends. Better adapted menus and more easily navigable menus lead to higher levels of acceptance by site personnel and more reliable data. Experience shows that even less well educated unskilled labourers with other mother tongues will readily and reliably use intelligently designed apps. Private experience in particular shows that this readiness and reliability is automatically increasing in step with people's affinity with smartphones and the Internet.

### The worker-machine interface: robots and 'exoskeletons'

The foreperson no longer heads a team of workers but a team of robots. Individual tasks are planned in precise detail and the robots communicate with each other. The foreperson monitors the work and checks the surrounding situation and the activity of other trades and professions.

Necessary input parameters ('ambient conditions', material temperatures, etc.) are measured by sensors which allow AI to make the relevant decisions about the process.



The foreperson only intervenes when the boundary conditions alter, when quality issues arise or when the robots cease to work as planned. Today, some complex installation work involving panes of glass is scheduled. The general phases of this work have been planned but fine tuning is required, which calls upon the experience of the skilled worker.

The assembly robot is equipped with artificial intelligence whose artificial neuronal networks allow it to learn individual tasks in the field. The foreperson demonstrates the activity and the AI of the robot records and analyses this and develops the necessary algorithm.

In the case of complex, unique constructional situations at significant heights above the ground the muscular power of workers is reinforced by the use of exoskeletons. This particularly helps in the case of assembly work carried out above head height.

**Analogy:** An analogy with the development of the automobile leads to the following observation: It was initially not unusual to have a chauffeur but tomorrow the 'self-driving' car will be a matter of fact. However, in a long transition phase the human driver will continue to carefully monitor the decisions of the autonomous car and be ready to intervene when required.

### **When something goes wrong – the supervisor or foreperson as ‘fire-fighter’**

The supervisor retrieved all his or her information first thing in the morning via apps and set all the relevant processes in motion.

But – at 10:00, work on façade FT15 comes to a halt. The robot installing the glass is not moving.

The system check from the control room shows that it must be an electronic problem.

The foreperson summons the specialist (who is informed by the on-call app and is available). The specialist travels to the site immediately and repairs the equipment. But the interruption lasted a couple of hours.

The event is registered in the system, the impact on the schedule is immediately analysed by the scheduler. A detailed report by the supervisor is registered in the system during the course of the day.

**Note:** Fully automatic systems are prone to error, intensive preventive maintenance is vital in order to minimise the risk of time being lost. System data are easily available as a result of which checks and maintenance can both be carried out remotely.

Around 13:00 a pane of glass slips from the suction cups. The foreperson is informed about this via his or her AR glasses and goes immediately to the given location on façade FT19. He or she checks the pane but there is no visible damage and even the detailed scan shows that there are no cracks. Hence, the foreperson decides that the pane can be reused and seeks confirmation from the resident engineer, who approves the course of action within the system.

The recording of the suction pressure shows a deviation from the norm and an analysis of the system reveals that there is an error in the angle between the suction cup and the pane of glass. The programming of the robotic arm must be adapted to this divergent geometry of the new glass fixing position. An engineer is informed and carries out the necessary adaptation of the remote control. A further three hours have been lost.

This event also has to be recorded in the system immediately.

Shortly before the change of shift the wind becomes stronger – in contradiction to the weather forecast – particularly on the side of the building facing the river. The foreperson, who checked the local situation again on his or her last tour of the site, leaves an additional message in the system and suggests to the construction manager that the night shift is reduced by one team. After the construction manager approves this suggestion in the system the affected night-shift workers receive notification directly on their mobile phones.

**Note:** The specialist with practical experience will also be an important figure in the world of the automated building site. Managers will plan and check in ‘virtual reality’ and gradually lose their relationship with practice. The foreperson is a generalist with common sense and practical skills and experience who makes suggestions about the approach that should be taken which the manager only needs to check and approve.

### **The final task of the day – planning for tomorrow**

In the evening team meeting at which the supervisor and foreperson are present, the revised plan for the next day is fine-tuned in discussion with the construction manager and the scheduler.

Real-time information about the production status and delivery information covering the entire supply chain facilitate the detailed adaption of the planning and, hence, the day-to-day synchronisation of the workflow on site.

But even in this world of thoroughly planned building there are deviations – the constant updating and adaption of the planning together with the scheduler and construction manager is one of the standard daily tasks of the supervisor and foreperson. Hence, the operational planning for the deployment of equipment is a significant element of the detailed integrated planning process.

However, meticulous planning does not always demand that the situation has to be examined in situ – difficult constructional situations can also be examined with the help of simulations within the 3D-model, while videos recorded by drones also illustrate the exact situation on site. Such recordings are also available for inclusion in the reports that the supervisor has to make every evening (daily report, accident report, quality report, etc.).

The modified schedule is then matched against the status of planned material deliveries and approved. This is thereby activated for viewing by subcontractors, clients or all other project partners who have the appropriate approval and can be used for the overall coordination of site activities.

That is enough for today – at least the supervisor had remembered early enough to book a taxi home from an Internet taxi service. The labourer is already looking forward to his trip home on his motorbike. The foreperson, who is very interested in sustainability, uses the excellent public transport network.

### 5.4.3 The future of handwork and industry

Let us imagine the construction of a house: with brick walls and a roof structure ...

#### Management in advance

The relevant contracts have been awarded and signed. The digital value chain is fully in place. The two selected items, masonry and roof structure, involve both designers and executing companies (architects, construction company) working within a shared CDE, Common Data Environment. All subcontractors and suppliers are digitally connected. Technical, organisational and administrative/financial processes are automated or, at least, supported digitally. The technical (BIM, design ...) and commercial (ProCS ERP) IT applications are compatible and managing the process as required.

The award of the contract to the contractor has been automatically passed on by the digital information chain to all members of the process chain to whom this particular process is relevant. During the submission of bids, all prices, conditions and technical aspects were linked together via IT where required, both internally (construction preparation, site management, administration ...) and externally (subcontractors, suppliers ...).

Open and standardised interfaces are used as far as this is possible and can be implemented. Here, data protection and levels of trust are taken very carefully into account.

IT bridges must be built for some project participants due to incompatibilities between systems. This leads to higher costs for both sides that have already been addressed during the submission of bids and included in the contracts.

Bids are submitted on the basis of a model. The BIM models of the brickwork and roof structure are included in the submission, tender award and contract models used by client and contractor. The attributes vary. General geometrical, technical, qualitative and quantitative attributes are retained at all stages whereas price and company-specific attributes only apply to the area in question.

This establishment of a hierarchy for both BIM and other digital information represents one of the greatest challenges of the coming developments.

The brick producer operates worldwide and is at the forefront in terms of digital strategy. The joinery firm is a classic crafts-based business and an SME that is striving to meet all the digital requirements placed upon it.

For both companies, the digital value chain starts operating the moment that the contract is awarded.

The requirements in terms of production and delivery are generated from the combination of BIM and ERP. The products contained in the offer are automatically flagged up for production, together with a precise classification. This classification includes category and number as well as product, part and charge numbers, which are based, as far as this is reasonable, on the current norms or standard specifications. This also includes all commercially and administratively relevant information as well as the timetable and all information related to logistics, process management, controlling and invoicing.

From the moment at which the bid for the sub-contract is submitted, the contract itself is digitally documented in the form of parts lists and scheduled delivery lists. Any adaptations resulting from the contract negotiations between client and contractor are incorporated retrospectively.

#### In the brickmaking factory

Just a few, qualified and IT-savvy workers control the order, delivery and invoicing at the headquarters and brickmaking factory. Prior to this, a number of highly-qualified workers have prepared the complex

software landscape and adapted this to the individual requirements, partly through in-house programming work. The commercial handling of the contract requires appropriately trained skilled workers.

The logistics software provides information about the brickmaking factories in which the required products are readily available. Automated storage and partly automated logistics ensure transport to the building site. The retrieval from the store and loading onto the truck is also automatic and the transport is basically autonomous, although accompanied. The site logistics system indicates the storage position, which is then reserved for exactly the right period of time. Unlike in the case of other products, just-in-time is not an appropriate approach for bricks. The unloading on site also takes place automatically.

The quality assurance in the factory is also another automatic process that involves the use of sensors, the testing of samples and a range of analytical methods. The taking and evaluation of these samples and the compilation of the report all occur without human involvement.

### Process management and control

The accompanying person is responsible for checking and, if necessary, intervening and managing the entire supply chain from the factory store to the building site. This person only has a basic expert knowledge about the factory, the project, the products and the systems used. They receive detailed information via a tablet. In the case of a problem (when intervention becomes necessary) this person has access to an emergency centre that operates company wide and is available to offer support 24/7. This centre is in contact with and, if necessary, can urgently supply virtually all the specialists required to ensure that delivery chains are not interrupted for long. This is particularly important in the case of just-in-time projects. One group of experts, which is fully independent from this emergency centre, is responsible for quality assurance and another



for administration and invoicing. This responsibility always includes developing, configuring, checking and, if necessary, adjusting. This responsibility also demands high levels of both expertise and operational readiness because it tends to be called upon when deficiencies in processes arise and it is essential to recognise and remove these deficiencies as quickly as possible.

**Note:** Changes that occur after an order has been given are a problem in the construction industry – today and in the future. A fully digitalised value chain means that it is possible to react more quickly and document and assign responsibility for these consequences more transparently. If, for example, the bricks are already on site the supply chain has to be restarted. Additional bricks are delivered and unused ones returned. The costs can be charged to those responsible for the change.

Experts in both the specialist area and the contract oversee this change process from scheduling to invoicing. Given that other project participants are also affected by such delays, experts in construction and building operations will still be required in order to ensure that such cases are managed carefully, despite the high level of digital transparency and automated process chains, and, above all, to avoid disputes and the resulting increases in additional costs.

### The joinery workshop

In the joinery workshop that is producing the roof structure a partly automated production process starts as soon as the definitive order is placed. The cutting requirements are generated automatically from the BIM



model and passed onto the sawmill, which produces precisely-dimensioned elements ready for delivery to site. From the moment at which these elements are stored at the sawmill the process basically corresponds with and is just as detailed as the process for the brick. All handling by fork-lift truck, crane and truck is controlled by humans.

Professionally trained individuals work in the sawmill, managing contracts and overseeing sawing machines, storage and handing processes. The control here is also digital: All workers have a tablet, which is used to pass on instructions, offer support and control performance. All administration of personnel and contracts is carried out via tablets and the central IT department.

### **On the building site**

The building site is largely automated and digitalised. The bricks are loaded at their storage position and transported to the position in which they are to be used under human supervision. This transport is driverless. The identification and loading is also automatic. Each charge of bricks is labelled using RFID and assigned information regarding its future use (building element, geometry).

Bricklaying robots are already so advanced that the construction of walls no longer requires manual work – merely supervision and intervention in case of emergency.

Reports to the site supervisor about the progress of work can also be made automatically in such a way that the resulting approval triggers the entire invoicing process.

Quality assurance also involves the use of machines, including drones that fly to inaccessible locations and cavity robots that move through and photograph narrow spaces. These machines involve a range of image-producing and analytical recording instruments that are “trained” individually in line with the needs of each building element and material. This means that it is also possible to draw up quality reports without human intervention.

Conversely, the assembly of the roof structure requires intense human activity, even if the building elements are delivered to the place of assembly by partly automatic lifting equipment. The handling of the rafters and purlins during this assembly process remains manual work.

## **6. Changes in job profiles on the building site**

### **6.1. General considerations**

It is indisputable that there will be changes.

A change can be:

- A concrete change, e.g. the transformation of a job profile
- A physical change in where that job is carried out
- The loss of that type of job

From the workers' perspective these three phenomena should be considered in different ways.

From the point of view of the Austrian workforce “relocation” can be understood in terms of two developments. On the one hand, the physical relocation of production to regions with cheaper labour and, on the other hand, the influx of cheaper labour onto the Austrian labour market. From the perspective of Austrian workers, relocation will always eventually lead to some form of loss.

This can be illustrated using the example of the automotive industry (a highly digitalised, automated and globalised manufacturing industry)

- Development is still being carried out in Central Europe: high wage, high expertise
- Production has been relocated abroad: lower wages, “progressively further away” in stages
- Use and operation continue in Central Europe (and everywhere else)

As a comparatively immobile industry the construction industry can only follow the same pattern in a limited way

- Development is still being carried out in Central Europe: high wage, high expertise
- Construction work remains on site

- Use and operation also remain on site
- The relocation of production abroad applies to some suppliers and staff procurement

These factors are to be taken into consideration in interpreting the impact of technology and digitalisation on the construction industry.

The global impact on the construction industry of lower transport and logistics costs and increasing real-time international communication is muted.

This study will deliberately not address the potential trade barriers that could arise due to current political developments. Attention is drawn to the side note in Chapter 7 regarding further economic and social observations.

The digital availability of information will simplify many things: The administration of the building site will become increasingly digital. Tasks that site team might currently see as examples of 'tiresome' bureaucracy will be digitally supported in future or could disappear completely. However, we have often seen that "apparent" simplifications in the world of work have actually led to unexpected complications. In addition to other skills there will always be a need for actual experience 'from the field' in order to be able to deal with unforeseen situations.

In future, however, there will certainly not be the same need for the number of people that one currently finds on building sites.

In general, one can expect the following changes in the construction sector:

- fewer personnel involved in construction and detailed architectural planning
- more personnel in prefabricating companies
- a reduction in 'middle management' on the building site
- fewer untrained labourers
- more personnel with IT skills, but who will work much more closely with operational personnel

In principle it is expected that the production of building components will increasingly shift to factories where they can be produced in more controllable conditions. This should reduce execution times on site and lead to more efficient quality assurance.

The role of the 'classical' labourer and even the skilled worker will therefore gradually shift from the 'production' of parts of a building in situ to the 'assembly' of individual components that are delivered to the site, as a result of which he or she will become much more of a 'manager' of completely automated processes. Specialist knowledge about materials and manual skills will, however, still be required because, in the near future, it will not make economic sense to standardise and automate every manual process.

## 6.2. The job profiles of today and tomorrow

Working methods on the building site of today are characterised by:

- Printed drawings that act as the key source of information – these are shared, used as documents in meetings or hang on the wall with colour-coded status information (and are not always kept up-to-date due to increasing operational time pressure)
- Talking together – of course mobile phones with all their varied potential are used for communication (as long as the signal is strong enough), but there remains a need for direct conversation wherever this is possible
- Information is distributed hierarchically: The project manager gives it to the site manager who passes it on to his team before the foreperson speaks with the labourer
- Individual tasks are discussed: at the morning meeting, ideally in situ on the building site and, if problems arise, solutions will be sought together in consultation with the relevant individuals and the individual task will be adapted as required
- Schedules do not enter into great detail and any adaptation in line with events as they occur is often the result of arduous rounds of consultation which include the strategic input of project and construction managers
- Administrative activities such as the writing of reports are generally the final tasks to be carried out before leaving site and are often regarded as a 'necessary evil', as a result of which they fail to receive the attention essential for the effective management of change orders

- The management of personnel and equipment including all such aspects as contracts, costs and forward planning requires countless lists, which are often difficult to keep up to date
- The organisation and control of materials on a large building site and, in particular, at the interface with the delivery process is a real challenge

The transformation on the building site of tomorrow will be felt by all workers:

- Information and communication will be increasingly digitalised and supported by technologies such as AR
- Everyone will be responsible for procuring information – information will be provided but not actively transmitted
- The control, organisation and management of materials, equipment and personnel will be digitally supported and capable of being carried out ‘remotely’: Sensors and microchips will permit feedback and control
- Individual construction tasks will be planned in detail within digital planning instruments as a result of which they will have to be regularly adapted in line with current events with the cooperation of the site personnel
- Knowledge about the process and the ability to find solutions will be required in the event of deviations and site personnel will be increasingly expected to be in a position to take decisions
- Administrative activities such as writing reports will be digitally supported and, where possible, automated
- Robots will be increasingly used to carry out difficult, repetitive tasks, especially in cases where high precision is required.

Hence, job profiles will develop in line with the following factors:

- Digital skills will be required in the areas of information, equipment and management
- The management of information via such ‘smart devices’ as smartphones, tablets, augmented reality and screen walls, etc. will shape the everyday reality of everyone on site
- Equipment, materials and, to an increasing extent, even personnel will become ‘smart’ thanks to the use of robotics, sensors and inbuilt microchips, etc. as well as communication via the ‘Internet of Things’
- Management roles in particular will require knowledge of such specialist software as ERP programmes, BIM software and timetable planning tools, etc.
- Increasing standardisation will lead to the transfer of work to factories or factory-like spaces with controlled conditions. Assembly will then take place on site. On one hand, this will lead to a shift of work away from the building site. On the other hand, however, other, broader skills will be required on site: ‘skilled work’ will only be partly characterised by a knowledge of materials
- The number of site managers and supervisors will not change greatly but a reduction in the demand for unskilled labourers and even middle management is expected. However, this process will also include a shift in responsibilities and the emergence of new roles.



Examined in detail, work on the building site of tomorrow will impact upon different groups of workers in different ways. Summarised and detailed comparisons – ‘today – tomorrow – development’ – for various trades and profession can be found in the appendix

### 6.3. New job descriptions

#### 6.3.1 Increasing complexity

It is generally expected that routine activities will gradually disappear. The tendency will be for tasks with a more complex context to become more common.

The remaining and newly emerging on-site activities demand training that involves a mixture of technical expertise, IT expertise and “operational readiness”. Here, however, the authors do not mean operational readiness in the traditional sense of being permanently available and committed but, rather, a form of operational readiness that guarantees immediate and expert intervention when problems arise. Similarly, in the case of support systems that offer assistance, the complexity and – for reasons of competition – essential ‘unbroken continuity’ of future value chains demand a completely new form of operational readiness. This involves expert and rapid reaction, the calm analysis and evaluation of every situation and the understanding that every second counts and that mistakes can have huge financial implications.

This assessment contradicts the view that the future supervision of automated value chains will only require lower levels of education and engagement. The reason for this is that, in cases of emergency, people will still turn to the digital handbook and the human support service for help.

Hence, the authors of the survey envisage that highly optimised and organised value chains will require extremely specific and highly trained individuals. In many other professions such as train drivers, dispatchers, mechanics, electricians, mechatronics engineers and drivers of construction machinery, etc., we have already seen such a transformation of job profiles in line with the requirement to be able to deal with increasing complexity. As in other professions, this is not a problem but it does require both time and training.

And one should also not forget all those who design and programme these highly complex and intensely interrelated processes. These will also be highly qualified individuals.

Considering the current structure of site teams, one concludes that it is the current team-leaders (skilled workers and supervisors) who should be required to obtain this new expertise. We see this as not only essential but also as a realistic possibility – and also the responsibility of the trade unions. But the involvement of other workers who are not listed here – for a variety of reasons – will create particular socio-political challenges in the coming years.

Precisely which roles will be affected – and when – is hard to predict. In any case, there will be a long process of transformation, which will also enable skill sets to be broadened in the medium-term and to be adapted in line with these new requirements.

In general, new possibilities in the areas of technology and communication and new business models in the sector will generate opportunities that will lead to either the creation of new roles or the expansion of existing ones.

It is to be expected that the increasing digitalisation of working processes will alter these processes in the following ways and, hence, alter the demands placed upon building site personnel:

- more digital organisation and planning of working processes
- more management / control of planned working processes
- more corrective actions, if the planned, pre-programmed routines do not work
- more collaboration – digital workflows with project partners

Such areas of activity can be addressed by relatively compact retraining programmes. The necessary specialist skills are already in place and workers must learn about identifying connections and be given the confidence to act on their own initiative.

A key skill of the S/F/L in this process will be to actively and autonomously source information from the common virtual workspace; In a similar way the S/F/L are also affected by the shift in the industry from the analogue ‘obligation to provide’ information to the digital ‘obligation to obtain’ it.

This process puts a premium on one of the most important skills related to information – the ability to question it.

### **6.3.2 Planning and organisation**

Site personnel are normally focussed on finding solutions to problems that arise during the course of their daily operational work. In future, the focus will shift to ‘thinking pro-actively’.



Site activities will be planned much more intensively and it will be possible to retrieve them as digitally available standard processes. Practical knowledge and experience in implementation will be required in advance in order to draw up this detailed planning.

This requires the early involvement of the site personnel and the combination of process-based and organisational know-how together with the experience-based knowledge of practitioners.

The S/F/L will be more strongly involved in the daily updating and adaptation of the planning.

The operational planning of both equipment and personnel is part of the detailed overall planning – but this must be optimised for the entire duration of the building site or the leasing contracts.

The basic criterion for the execution work on site is the smooth organisation of the necessary deliveries. Materials management and logistics will be completely digitalised and will proceed automatically. The intense merging of production and supply-chain information will make it possible to organise deliveries to the building site with much more efficiency

However, this will also demand a more sophisticated approach to overall planning in which all processes are precisely coordinated. Supervisors and forepersons will be increasingly involved in this scheduling work and ‘early involvement’ will become a decisive success factor.

### 6.3.3 Prognoses and controlling

The “zero-tolerance” of interruptions in the value chain that is likely to be triggered by both commercial and security considerations will bring new challenges. This can be compared with developments in air travel today. There will be an increase in check-routines and this will require preparation (in terms of time, cost and training). In turn, this will increase the demand for controlling (process management) skills.

Forepersons and labourers will control the process of installation in situ on the building site via a human-machine interaction (exoskeleton, direct work e.g. on a cherry picker with a robotic arm, which can be flexibly programmed by the worker; etc.) This will lead to an increasingly symbiotic relationship between worker, machine and robot.

The supervisor of the future will sit in the control room monitoring standard processes and will only intervene in cases of deviation from these processes. Work will be increasingly taken over by machines. Machines will largely be fed with information directly via the ‘common virtual workspace’ in which the planned sequence of work has already been modelled and synchronised.

We are handing over more and more work to machines while retaining responsibility for the perfect functioning of the resulting digital and automated value chains. Self-learning robots equipped with artificial intelligence will enable us to constantly improve the operational quality of both these value chains and our digital control systems.

### 6.3.4 Deviations and corrections

Despite any amount of preparation, deviations from the plan and unexpected situations will always arise on site.

Generally, corrective measures are required in two areas:

- External disruptive factors: Adaptations to the planned process caused by external, unpredictable events
- Internal disruptive factors: Digital / mechanical / electrical malfunctions and corrective measures / repairs / adaptations to the programming, which became necessary when hardware fails to work correctly

The important thing is that both external and internal disruptive factors are avoided or their impact is minimised: by better processes, by the continuous control of these processes and by better machines (including better software).

Immediate action is required when unexpected malfunctions occur (e.g. when IT information chains do not work, equipment fails, IT QA sensors report that the quality is inadequate, etc.) These ‘emergency skills’

must be taught more intensively. This requires workers to have both IT skills and basic knowledge about the robotics used in a project.

This will lead to new job profiles. In future, the supervisor will be involved during the development of the tender offer in the role of 'pre-risk-analyst' and will be responsible for outlining and attempting to avoid all potential practical risks (both external and internal risks, on the basis of his or her experience and specialist knowledge). Well-thought-out plans for any expected malfunctions will be prepared and retrieved in case of need.

In addition to this, there will be a need for 'special troops' who will be deployed in unexpected situations in order to solve the problem. This will require practical site experience, detailed technical knowledge and a problem-solving ability based on speedily assessing situations and recognising connections.

### **6.3.5 Digital collaboration**

Digitalisation will lead to an increase in the exchange of information with other project partners on the basis of digitalised workflows. Above all, this will also involve direct exchange with clients, statutory authorities and other trades and professions and directly impact upon communication on the building site.

This means that the issue of 'digital collaboration' will not only affect site management but also have a direct impact on the working methods of S/F/L. All site personnel will have to seriously address the developments described in Chapter 5.3 and develop the necessary understanding of processes and software. The skills required to achieve this must be addressed in both training and education.

### **6.3.6 Social skills**

In addition to the need for digital skills there will be an increasing demand for social skills. Essentially, these are not 'new skills' and they were always important – but they will be much more clearly on the radar in future, even for 'non-management personnel' on the building site.

Despite the fact that the supervisor and foreperson of the future will have to spend more of their time managing robots, the management of workers and the coordination with other project partners will remain key tasks. Smooth cooperation within the site team and a solution-oriented approach with project partners will be decisive success factors for a project.

This means that the demand for 'soft skills' such as conflict management, critical faculties and the ability to deal with a range of ethnic groups and mentalities will increase and these will become key qualifications for building site personnel. Despite – or perhaps even because of – the increasing volume of digital communication the importance of the direct exchange between people will grow.

It is also essential that education and training place the necessary focus on this area.

## **6.4. The potential for new job descriptions**

### **6.4.1 The labourer as the key interface between the digital and real worlds**

One option for the labourer is to establish him or herself as the key interface between the digital and real worlds.

The access to all necessary information provided by the 'common virtual workspace' means that the manager is no longer required for certain steps. The labourer's experience from the field, in combination with standardised processes that are filed in the system as 'blueprints', places him or her in the position of being able to take or at least prepare his or her own decisions. These skilled building workers can be involved in drawing up such processes and then implement them on the building site with the help of the available machines and robots.

A further option is to develop the labourer into the 'manager of the robot'. This involves, on the one hand, control and monitoring and also, on the other hand, the management function. Human workers can evaluate changing parameters much more precisely in order to reach speedy decisions about the routines that should be applied. Robots should be seen as 'tools', as systems with physical and virtual components which, while highly complex and networked, essentially help human workers and should leave them to

make the final decision. But human workers are definitely required when the system makes or reports a mistake.

In any case, it should be borne in mind that the human worker is a model for the robot. Not only in terms of the general development of the individual programmable tasks but also in terms of the use of ‘artificial intelligence’. For while AI may be able to develop algorithms with the support of a structure similar to one of the neuronal network structures of our human brain, it also requires any task to be demonstrated in advance in order to develop of this algorithm in the first place. This means that the labourer will always be required – as the trainer of the robot.

Of course, things could move in a direction in which highly-qualified and expensive graduates are used to manage robots. But by giving them the right skills in good time and encouraging an openness and, hence, a readiness to develop in this direction, skilled building workers could also fill this gap.



Such an approach could lead to the emergence of a new type of highly-qualified skilled worker. However, it should also be noted that experience and manual skills are a prerequisite – qualities that are difficult to obtain in a fully-automated world. In addition to this there is a risk that the increasingly automated building site – which functions optimally on the basis of ‘machine-to-machine’ communication – could lead to the loss of vital knowledge about processes.

*When processes are wrongly or over-automated, those who monitor them and are required to intervene in emergencies risk losing precisely those manual, cognitive and monitoring abilities that they urgently need when something goes wrong. Such knowledge and intuition develops in the daily interaction with the equipment or process. The understanding of a process that is readily spoken of as a required qualification is not at all easy to develop and to retain in the case of highly complex, closely-linked processes based on machine-to-machine communication.*

*From 33*

#### 6.4.2 Pre-risk checker

Due to the stringent requirements of the preliminary planning phase it is becoming increasingly important to be able to assess the situation on site in advance. BIM permits the planning of construction process scenarios and, hence, the optimisation of site activities in a comprehensible 3D-model. This will also allow complicated construction situations to be thought through in advance and risk assessments to be carried out – as long as experienced site personnel are involved. As a result, it will be possible to predefine processes for crisis situations that can be retrieved and activated at short notice when needed. Such ‘manuals’ can also be prepared in advance for the flexible use of construction machines and robots.

Today the process is run by managers while a number of people are involved in ‘analogue’ roles.

However, the future ‘pre-risk checker’ will prepare a digital Emergency Case Manual that describes the speedy and correct (tested and checked) actions that can be taken to in order to prevent mistakes occurring as a result of improvisation and, hence, minimise delays or further commercial consequential damage.

When such situations occur all the relevant information is available in the common virtual workspace and the expertise of other team members can immediately be called upon via digital communication as a result of which decisions can be swiftly organised.

This process will always require practical field experience and only human workers are in the position to comprehensively and speedily assess complex situations and initiate the next steps in risky, unpredictable

situations from the health & safety and security perspectives while also taking into account the input of other trades and professions and the current, local weather situation.

It is thus possible that, in the future, one could find fewer managers working on building sites and, in their place, well-prepared and experienced skilled workers, who will increasingly assume traditional management roles.

### 6.4.3 Emergency situations

In addition to the maintenance work that is usual today the building site of the future will also require task forces ready to respond to emergencies during building operations.

It is conceivable that there will be a service point ('workshop') for digital, mechanical or electrical malfunctions, which is always on standby, ready to repair problems in situ – in a similar way to the IT support teams in the larger offices of today. Special units could concentrate on the situations in which robots are employed – 'Robotic Maintenance': a mixture of programming, manual repairs and electronic know-how.

A regular payment could cover the provision and use of the service and, if necessary, the supply of replacement machines – this could be a business model of the future.

In the case of large building sites, this service could be provided internally – on a different level it could be provided by a decentralised emergency unit for SMEs. It would certainly be easier for medium-sized construction companies to adopt digital and automated processes if it could be guaranteed that such 'Digital Emergency Support Units (DESUs)' were available in a business location. Such central provision could form part of a location development strategy.

### 6.4.4 New areas of work

The developments described above enable us to recognise completely new opportunities for the use of skilled building workers.

There will be a need in future for experts in all aspects of automation and new technologies such as:

- new building materials (e.g. geotextiles)
- drones, laser scanners, 3D-printers,
- robotics
- MSR (measurement, control and regulation technology) and
- sensors

and in all aspects of the increasing digitalisation, such as:

- IT support
- construction scheduling (a combination of material organisation, supply chain management and quality monitoring) and
- digitally supported building maintenance (in the field of facility management).

## 7. Society and sociology

### 7.1. Freedom and responsibility

The challenge of ensuring that the unavoidable, upcoming digitalisation works in the interests of freedom and responsibility rather than oppression and control is probably THE central socio-political and democratic challenge of the next few years. And, as we rise to this challenge, this regulation of responsibility involves not only defending our underlying transparency but maintaining control. The task will be to use the transparency created by the universal availability of data to trigger – and create the political framework for – positive social developments.

Today's democracies are hardly prepared for this task.

And neither are our social policies.



Samantha Smith, Director of the Just Transition Centre, an initiative of the International Trade Union Confederation and partners



The task outlined here is both basic and complex.

It impacts upon work, the economy, the media, health, education, taxation, social security, justice ... hence, in reality, all areas of our society.

Comparable developmental leaps faced by society have probably included the introduction of printing and radio/TV or, in other words, earlier quantum leaps in the spreading of information. Each of these information revolutions had significant social consequences that could hardly have been imagined just before they occurred and were unwelcome to and, hence, opposed by many beneficiaries of the previous situation. This opposition took the form of religious, political and economic inertia in support of the status quo.

## 7.2. Steering digitalisation

Hence, the task is to predict and pre-emptively steer the effects of digitalisation upon not only society as a whole but also affected groups and individuals in a positive direction.

This “pre-emptive steering” must be thought out in advance in the light of this expected inertia. Who will stand in the way of the desirable developments? Where can alliances be found and built? Which strategies and tactics are to be developed?

The first task is to recognise what is “desirable” in the eyes of all participants and those who are affected in other ways. Democratic societies are based on balance, on trade-offs. Progress often leads to imbalances as well as to unexpected and undesirable results because those very results are imponderable or cannot be predicted in advance.

Recognising and offsetting these imbalances in good time is the most important task if one is serious about wanting to avoid hardship, revolution and war.

On the other hand, the search for balance should not be allowed to get in the way of progress. Progress means new opportunities, even if these involve risk.

The three qualities of humanity, sustainability – in our approach to nature and resources – and economy – in the sense of efficiency and the pursuit of reasonable profit – should not be seen as opposites. Rather, politics should create an environment that encourages equitable balance.

In terms of the subject of this study, this breaks down into the following steps or levels of observation:

- In which direction are technology, innovation, digitalisation and data environments developing in the context of work on the building site?
- What will be the resulting impact on the careers and working environments of individuals? How can we become involved and benefit? What will happen otherwise?
- What must individuals do (careers) and how must the context change (working environment)?
- This working environment stretches from the team leader via the company management, the specific customer within the procurement chain to public and private clients and the domestic and international political context.
- What can be done today to take advantage of opportunities, minimise risks and offset any consequences? ... in the short-term.
- And what can be done today and tomorrow to set the right course for the medium and long terms?

*It is important to understand that the impact of digitalisation should not only be seen as being determined by technology. Such opportunities are difficult to justify from a purely economic perspective. The key is the interaction between technology and user behaviour.*

*Freely adapted in line with the interview with J. Flecker and 33:*

There is an opportunity here for social and political intervention, which must be taken advantage of early enough in order to be able to influence future developments. The starting point of these future developments



is often hard to assess and has to be simply accepted. This means that there is a need for permanent accompanying analysis and a continuous scrutinising process.

### 7.3. Data and data protection

Broken down into the areas of digitalisation and data, this demands a differentiated approach, which first has to be researched and implemented in democratic and socio-political terms. For politicians this is digital virgin territory. One can often see this in the inability of political systems to address such issues in relationship with tax systems, educational policy, global companies and start-ups, data transparency in health policy and cyber-criminality, etc. ...

Two concrete examples:

- Building work data will be completely recorded in future. The presence and working hours of building workers will be digitally recorded and their position and movement patterns in the factory and on site will be accessible online at any time. Machines and materials will be captured in the same way in terms of movement, performance and error data. But how will we be able to use this data in the future for the benefit of workers, the economy and the location where we live? And how will we be able to prevent all forms of misuse?
- Health data, including data about illnesses, will be completely recorded in the future. Every sport app represents a step in this direction. The questions are very similar: How will we be able to use this data in the future for the benefit of workers and the society in which we live? And how will we be able to prevent all forms of misuse?

As far as the authors of this study have been able to identify from the literature and from our discussions, there is as yet no generally recognised or even reliable answer to these questions.

Social consensus, however, demands that data are safe from misuse. This will be one of the key issues of future democratic societies. We will take for granted that our data will be recorded from childhood. But how we avoid the misuse of this data by a dictatorial society is, today, completely unclear.

Digitalisation is facilitating a technology in which everything can effectively be accessible. Access to data and information will be the major power-related issue in the future.

Digitalisation cannot be avoided; each of us will have to deal with it in some shape or form. The decisive thing in this process is a critical approach to data. 'Fake news' or 'alternative facts' are not new but direct person-to-person contact has previously offered the empathic human the opportunity to directly assess his or her counterpart. However, digital provision means that it will be harder and more costly to evaluate the truth of such content. The permanent flood of information and access to data can easily lead to overload and increase the possibility of 'demagogic seduction'.

The ability to question information and assess the validity of data will become an essential skill for everyone – whether they work in a digital environment or are only indirectly affected.

In an increasingly digital environment the emotional aspect of the fear of losing control cannot be underestimated: The focuses of this fear are the misuse of personal data, whose trajectory in the virtual world is difficult to understand, and the possibility of manipulation due to the selective use of information.

The potential scenarios in non-democratic systems are dramatically demonstrated by developments in, for example, China and Russia.

### 7.4. Demographic and socio-political developments

The following topics will lead to enormous changes:

- The separation between work and leisure will continue to diminish – fluid permeability
- Location dependence will continue to disappear, workers will become more mobile but the place where work is carried out will also become more flexible – home office, global teams, etc.; in virtual reality the project is location-independent; but construction is always location-dependent
- Solidarity and the political approach to the 'other' are currently undergoing a transformation – the approach to poverty and refugees – who should be allowed to work? Is working or, more specifically, finding self-fulfilment through the act of working a basic human right?

- Women will be found in the construction industry – and on the building site – in greater numbers
- The lack of skilled workers will increase due to the change in the skills that are required
- The population is aging: We will work much longer but also in completely different ways

It is generally to be expected that demographic change will lead to the emergence of new jobs.

Female workers are still uncommon in the construction industry. And while equal opportunities mean that more women are now working as construction engineers or designers in offices they remain rare on building sites.

On the one hand, this is a result of a persistent adherence to convention – ON THE PART of both the construction industry and women themselves while, on the other hand, some site work is so physically challenging that women should not reasonably be expected to perform it or would simply not consider doing so. However, certain technological developments that are reducing the need for such muscle strength will make the building site more accessible to female workers.

Another special subject connected with digitalisation is the demographic structure of the population. The way in which increasing digitalisation will impact upon current social, political, administrative and economic relationships will certainly be influenced by our age and educational background.

How easy will it be for older workers to adapt to digitalisation and acquire the necessary skills? This is not only a question of age but much more one of flexibility and the ability to learn.

The following are to be taken into account:

- flexible forms of working between the ages of 60-90 will become the norm
- older workers must learn to “downgrade” – to earn less ... to support and help
- there is a contrast between the fluid intelligence of youth and the crystalline intelligence of age

fluid: the ability to learn quickly, cognitive skills.

crystalline: linguistic ability, broadly-based knowledge, an eye for essential relationships.

- the advantages of the old: social integration of information, pronounced decision-making ability
- Freely adapted from 54*

In any case, consideration should be given in future to the fact that, in the next generation, EVERYONE should be a ‘digital native’, who will be at home in the virtual world as a matter of course.

## 7.5. Work and income

In a society in which income is an important element of our life planning and unemployment is regarded as a central social issue, work and income are two important issues that must be addressed.

Every industrial revolution has resulted in greater prosperity and less work. This is also the basic expectation of digitalisation. But transitional phases are always difficult. These have often been characterised by revolutions or, at least, difficult times for some sections of the population.

However, there is also room for intervention that must be actively used. It is not automatically the case that technology will determine what happens while workers must adapt. This discussion has to be carried out in a broad social context and on the basis of values.

*The prognoses discussed in this area are currently highly technology-oriented. The impacts on work and society are often falsely understood as obligations upon workers and the working regulations to adapt to the new technical working environment. However, this underestimates the latitude and range of imperatives in shaping society. And it is far from certain how such work will develop.*

*From [33]*

The above study expressly points out that there is some room for manoeuvre in how work is organised in the future digitalised environment. This means that we are able to qualitatively and quantitatively shape working conditions in a way that counters any tendency towards a polarisation between ‘high-tech’ jobs for graduates and ‘low-end’ jobs for unqualified workers.

It is possible to imagine organisational forms in which smaller teams are given responsibility for their own actions and for achieving their own objectives. These teams will organise both themselves and their route to their goal. They will be given the external support of a transparent controlling system. In this sense, hierarchies will change in a way that also meets the expectations of a society that has become 'more mature', not least as a result of digitalisation.

The focus here will be sociological and technological processes designed to promote collaboration. Based on the principles of 'agility' and 'leanness', this collaborative approach will lead to more successful construction processes and projects. However, it will also demand massive changes in comparison with previous organisational forms. This means that opposition is also to be expected for which one should be adequately prepared.

These 'change processes' should involve all levels of an organisation from the very start: in other words, including the labourers. For the new organisational forms in the construction industry that are likely to emerge from digitalisation, this represents a completely new way of looking at things. It will also take longer before this transformation has been completed and this process must also be prepared accordingly. It will face a lot of scepticism. For this reason, the success factors for and the opportunities of and threats to this process must also be clearly established and followed.

The objective of all these developments must not be to maximise the amount of work that is replaced by automated processes. For people have an intrinsic need to work, an important aspect of which is the opportunity to sense their own 'effectiveness'. Creating this opportunity is a key responsibility of society.

According to [33] these opportunities must be consciously promoted.

In using these many opportunities for shaping the future we must not overlook the humanisation of work. This is not automatically linked with technical progress. On the contrary, we must continue to strive to make work meaningful and educational for workers.

## **7.6. The interaction between humans and machines**

The focus of the current discussion is the division of work between labourers and machines.

In part, this involves very detailed consideration of individual tasks: what can be automated? What can be taken over by robots or 'machine-to-machine communication' in the light of rapid technological process and at an economically logical scale?

*The core question in this area is, however, whether robotic technology should basically be seen as a tool for supporting human work – a tool that has access to a multitude of information from the digital environment on the basis of which it can take decisions and control its 'fleet of machines and robots' accordingly (the 'machine as tool' scenario). Or, whether we should strive for "the highest possible degree of automation in the form of self-controlling, decentralised production resources" in which human workers should be replaced and control should be exclusively carried out by centralised control units (the 'machine as automation' scenario)*

*Based on 33*

In this discussion it is important to note that, even in the case of the automation of routine work, processes can only be automated to a certain extent. In particular, time is needed for the developments that are required before such steps are economically justifiable. And during this 'transition period' there will be a particular demand for human intelligence in all its complexity.

The important thing for companies is to aim for a successful integration between technology and the working process (and, hence, workers). This requires that companies develop both expertise and also flexibility (in the sense of the ability to use workers for several different tasks). It also requires holistic approaches: Work must be designed in such a way that workers develop a good understanding of processes and learn not to lose sight of the 'overall, optimal solution'. The field of activity and the direct structure of work should encourage 'learning' and offer enough leeway to permit workers to draw their own lessons from situations in which 'it didn't work,' without having to feel guilty and compelled to defend themselves. Of course this is also a question of corporate culture.



*Seen from this perspective, the replacement of people by machines is not an unavoidable result of technical change but, rather, a development that will enable a company to take advantage of the overall potential of its human workforce. At the same time, automation underlines this opportunity, creates the necessary freedom and, naturally, makes an economically positive contribution. The objective must be that “people are supported in this process and able to work ‘with’ rather than against the networked system.”*

*From 33*

This brings many advantages for companies. Including the fact that processes will become more flexible and less susceptible to malfunction. In the context described above workers will develop not only important skills but also the desire to implement the process entrusted to them, in cooperation with their team, reliably and to the appropriate quality.

An example is provided by the following development in the manufacturing industry:

*In the cases investigated by Windelband/Dworschak (2015) in which lightweight robots are used to carry out welding work the programming and making good of defects is the responsibility not of welders but of highly-qualified programmers. The welder is dealing with a “black box”. In contrast with this, in the assembly of heavy components of very small flying objects the lightweight robots support the assemblers, who retain responsibility for planning and control while being given ergonomic support.*

*From 33*

However, the interaction between ‘man’ and machine should also be seen in a much more direct context – the border between man and machine is shifting in the direction of ‘human hardware’. Cyborgs are no longer merely figures from futuristic computer games or science-fiction films.

Exoskeletons – mechanical, motorised tools that are worn on the body and support human work – will become an increasingly common sight on building sites. These are an externally visible signal. But software will also be increasingly directly combined with the human body. Implanted data chips directly feed information about physical positions and processes into – or, inversely, draw impulses from – ‘virtual reality’. On the one hand, this brings the danger of the misuse of the ‘transparent individual’. On the other hand, there are people who think that it is hip to be a ‘cyborg’ (see ‘Salzburger Nachtstudio’ in OE1, 6.3.2019). Science-fiction shows us one direction in which this could go: e.g. TV series in the 1980s that featured symbiotic – half machine, half man – beings.

Another very old subject is robots and emotions. While emotions are seen, on the one hand, as being a privilege enjoyed by humans there are attempts, on the other hand, to develop robots that are human in appearance and able to ‘simulate’ feelings. This humanisation of the robot should be questioned – why do we even want robots to resemble us? What is the limit to Blade Runner? (The 1982 film by Ridley Scott).

Visions of the future that take us in a completely different direction can be found, for example, in the novels of Iain Banks that describe the amicable and equal co-existence between artificial intelligences (‘minds’) and people.

To summarise, one can say:

- the approximation of ‘man’ and machine is leading to a new notion of “naturalness.”
- we must end the ruinous rivalry between the brain and the computer.
- humans must make the most of their strengths – such as emotion, intuition and creativity, etc.

*From 54*

## 7.7. New project areas

In addition to the direct relationship between digitalisation and society and the impact of this relationship on workers we must also consider that the associated social developments and shifts in values will produce completely new areas of intervention for building projects.

Firstly, digitalisation and smart technologies will have a direct impact on our built environment. Urbanism will be reinvented in the form of ‘smart cities’ and urban planning and new infrastructure requirements will transform built-up areas.

Increasing demand for energy will necessitate the expansion of the energy supply. The development of the digital surveying of the existing will also generate new projects.

But, most particularly, the demands of society for a sustainable approach to resources will increase the demand for construction services in areas such as the following:

- New forms of energy such as geothermal energy and the use of solar and wind power
- Energy supply infrastructure such as supply lines for the electricity grid – the ‘power grid’
- • Water supply infrastructure, especially in urban areas
- Recycling – the material cycle
- The cleaning of contaminated sites
- New forms of mobility designed to reduce private traffic (e.g. urban ropeways)
- The refurbishment of existing buildings

The impact of climate change is also being felt ever more strongly and constructional measures will be required to protect inhabitants. On the one hand, these include flood and avalanche protection measures that will enable us to deal with extreme weather situations. On the other hand, rising levels of drought at our latitude will demand the development of comprehensive irrigation systems for agriculture.

## **8. Areas of investigation**

Chapters 8 and 9 summarise the key results and recommendations of the study.

These are structured in line with two important documents

- The Study of the Potential of Digitalisation in the Construction Industry, by the Institute of Interdisciplinary Construction Process Management (ibpm) of Vienna University of Technology for the Federal Ministry of Transport, Infrastructure & Technology (BMVIT) and the Construction Section of the Austrian Economic Chambers (WKO Bau)
- The Digitalisation Roadmap for Design, Construction and Operation in Austria of Plattform 4.0

The following areas are investigated in Chapter 8 in terms of their relevance to the focus of the study

- Political, social and legal parameters
- Corporate and project processes
- ProCS Procurement (tender/tender award), contract & settlement
- Tools and the interoperability of software solutions
- Research and development
- Education and training

### **8.1. Political, social and legal parameters**

This area of investigation includes political measures both at home and abroad. It covers the entire range of political and legal parameters that affect the application of digitalisation in both society and business.

This study has a narrow focus: The construction worker and, more specifically, the supervisor, the foreperson and the labourer.

Political and legal parameters must be created that are designed to maintain or improve the working conditions of these workers or, in the light of the impact of digitalisation, to update their working conditions in such a way that they are once again satisfactory. The study deliberately avoids describing all the political and legal parameters required in order to prepare and accompany this transformation – which is probably the greatest social and economic transformation that we have experienced in many years.

It will concentrate instead on the following areas of investigation and recommendations for action:

- Jobs and the quality of work
- Working hours
- Wages
- The tax system
- Handling data
- Health and environment
- The image of construction work

### 8.1.1 Jobs and the quality of work

The following basic changes will occur:

- Jobs will change and job profiles will be transformed.
- Jobs will change location, workers will move with them or jobs will be taken by new workers.
- Jobs could be lost as a result of rationalisation and automation
- New jobs could emerge, with new requirements and specialisations.

The quality of work could develop positively or negatively. On the one hand, digitalisation could lead to the creation of much more challenging jobs. On the other hand, extremely undemanding and, hence, “cheap” jobs could be created in connection with supporting machines. This situation is particularly likely to arise if unqualified workers are cheaper, in the long term, than the development and use of machines for specific processes.

In other words, the challenge will be to train people to take on the new, more challenging jobs that are going to be created.

A further challenge will be to strengthen people’s understanding of the need for mobility in such a way that they are also prepared to respond to economic necessity and financial incentives by taking these new jobs wherever they are created.

In return for this it is also important that jobs are not allowed to move abroad due to misplaced political, economic or tax incentives. That is to say, we must aspire to keep jobs in places where highly-qualified personnel are already available.

Taking this further, another challenge will be to maintain the supply of highly-qualified personnel who are available to perform these existing and retainable jobs tomorrow and well into the future. In concrete terms, this means that we must, for example, maintain the high number and quality of jobs in Europe and also ensure that we have suitable workers for carrying out these jobs in the future.

This means: investment in training and education, from apprenticeships to universities, in line with the demands of future jobs.

This also means keeping an eye on demographic developments. There is no doubt that the number of young people in these countries will fall in future. This will lead to the question of whether digitalisation will reduce the demand for young people in working processes at a rate that avoids shortages of skilled workers.

If this is not the case – as is currently assumed – it will be essential to create political, social and legal parameters that permit the influx of new workers at a rate that meets the future needs of industry.

It will also be important to test a range of politically and scientifically-based scenarios of the relationship between demography and digitalisation over the course of the coming years and decades.

In addition to quantitative analysis and planning (keyword: jobs) there will also be a need for political and scientific research and planning at the qualitative level (keyword: the quality of work).

A key aspect of this is set out as follows: It is possible that it could become technologically completely feasible to develop and use machines that can take over routine tasks without any need for human input (except in the areas of development, management and control). In purely economic terms, however, cases could arise in which it is simply cheaper to allow really unattractive routine processes to be carried out by



unqualified, poorly-paid individuals. Our responsibility is to research this area and introduce controlling measures that prevent such processes from occurring or proliferating.

This example alone demonstrates the complexity of these relationships and the extent to which technology, business, politics and society have to intertwine and work together in order to counter any negative – and encourage all positive – effects of digitalisation.

This complexity is overlaid with the issue of globalisation. No country and no business location can seriously believe that it is in a position to meaningfully solve future developments alone (and, possibly, in the face of the opposition of others) even if certain efforts currently taking place on the international political stage suggest that there are people who imagine that this is indeed possible.

In this sense, all political, social and legal parameters should be seen as cross-border and international.

Analogies from other economic sectors in which digitalisation is already more advanced can offer us important clues about measures that should be taken by the construction industry. It must be noted, however, that certain aspects of the construction industry, with its unique character and obvious inflexibility in terms of location, will develop very differently from other industrial and commercial sectors.

In conclusion, one can say that the issue of jobs raises the (sometimes conflicting) priorities of ‘retaining’ and ‘creating’. The basic objective of a society should be to ensure that enough jobs are available. In this context we must increasingly think trans-regionally and globally and discuss migration in a meaningful context.

Certain jobs are bound to become obsolete as a result of increasing digitalisation but new ones will also be created. Obviously, it is currently unclear how the overall number of jobs will develop and how such developments will effect individual sectors.

### 8.1.2 Working hours

Working hours is a subject that involves both ‘health’ and ‘wages’ as well as aspects of ‘availability’ and ‘duration’. But they must be addressed in the context of the general distribution of labour and the trend towards a reduction in the amount of time spent working.

Working hours have a causal relationship with the quality of work and, together with the issue of wages, can have both a subjective and an objective impact on health. The phenomena of stress and burnout are already discussed intensively today in connection with digitalisation. Not only, however, in terms of the required professional availability but also the private use of information, which often cannot be distinguished from the professional use of information.



Digitalisation is leading to a general tendency for people to be involved in “data-based work” around the clock. Even if this is not demanded contractually, the notion of permanent availability and the merging of the professional and the private are leading to extremely dangerous developments.

This means that working hours cannot be evaluated and organised as before. When one checks out of a building site, factory or office one generally no longer checks out of the data chain.

The authors of this study are open about which basic recommendations for action are required in order to regulate working hours in the digital age. Indeed, it is assumed that regulations alone will not be enough or



will be unable to impose themselves. It is much more likely that social norms and customs will change or that people will become more enlightened or differently motivated.

However, there are already signs that people are becoming aware of the negative effects of the permanent exposure to data and of the fact that “data pauses” are an important quality-of-life issue.

Hence, whereas attention was previously focussed on the regulation of working hours and prescribed work breaks the future focus will be on “the regulation of data hours” and “data breaks”. How these are best implemented within society is an important question for future research.

A further key aspect of working hours in the context of digitalisation will be the extent to which our working hours are reduced by the use of digital tools, machines and robots.

Will we find ourselves in a society which, in the medium or long term, offers much less work than today's? To date, every industrial revolution has led to such a development. The working hours and conditions that prevailed 100 or 200 years ago would be unimaginable for us today.

Of course, this comparison applies to neither the highly-privileged members of past and present societies nor the underclass of today. This is another subject to which we must devote ourselves as a society, and not only in connection with working hours.

How will we succeed in sharing out both the total amount of work available and the total appropriate remuneration for that work in a way that is seen as fair and meaningful by society as a whole? We will examine this question further in the next chapter, “Wages”.



The following examples highlight several aspects that must be researched and addressed in terms of ‘working hours’.

Today's building sites already operate 24/7. The increase in automation and the use of robots will make this unavoidable: the use of expensive ‘production machines’ demands a high utilisation factor.

This demands a sensible organisational approach, with logical shifts for site personnel. This will lead to new requirements in terms of the number of workers and also the organisation of working routines. In such a case adequate numbers of specialist personnel or workers with leadership responsibility must be available for every shift.

The digital recording of working hours raises another issue: When do these working hours begin? Over an entire working life this detailed question has major consequences. Are the limits of the working hours related to the limits of the site – e.g. they begin and end when one enters or leaves the site? How are working breaks dealt with? This will require detailed rules, possibly for specific application to building sites. This could also easily work to the benefit of workers: Seamless time recording could make ‘unpaid work’ very unlikely. Transparency would be an important outcome.

Special attention must be paid to the subject of flexibilisation: of ‘work on demand’. In order to economically optimise a building site under future parameters (robotics, automation, continuous communication which is independent of time) the ability to deploy workers flexibly will be essential.

This, in turn, will demand the appropriate contractual agreements with the companies working on the site. Appropriate rules and fee structures for flexible ‘on-call duty’ are to be agreed.

These developments are not only apparent on building sites – the dissolution of the inflexible seven-day rhythm is a general socio-political phenomenon. The impact on family life, health – and on the ‘work-life balance’ in general – should be analysed.

*But we should also take advantage of the flexibility of production technology in terms of the flexible use of personnel. A report by the Fraunhofer-Gesellschaft cites “increasing variations in capacity requirements for*

*personnel during the course of a day” (Ramsauer 2013). This subject demonstrates the advantages of “Industry 4.0”, while also promoting organisational models that respond to the trend towards “work on demand”. In addition to flexible time planning, functional flexibility (in terms of the organisation of work and use of personnel) should also be considered: How can workers, particularly low-skilled workers, be switched between departments and teams on demand? This reveals a close connection with the question of qualifications, but also of work-life balance (cf. Chapter 8).*

From 33

### 8.1.3 Wages

The basic rule should always be that any work that is performed is rewarded as justly as possible. And yet this “justice” can never be achieved perfectly and is, in any case, usually impossible to evaluate objectively. Hence, remuneration is more a question of the subjective satisfaction of the wage earner.

Following this general “psychological and philosophical” statement it is necessary to analyse how digitalisation will impact upon the remuneration of work. If one accepts the normal argument of the current debate, digitalisation will lead to a strong reduction in the total amount of work available. This will apply initially to developed countries before progressively spreading to other regions.

#### Analogy:

An analogy can be drawn here with the general development of the global population. Increasing industrialisation and improving health and healthcare provision lead initially to a dramatic fall in child mortality rates and a rapid, short-term growth in the population. Thereafter, a reduction in birth-rates leads to a levelling out or even a reduction in population levels.

Fundamental social developments and upheavals lead to not only new demands and new opportunities such as education but also transformations in social roles such as the new role of women in today’s society.

Hence, one can safely assume that digitalisation will lead to fundamental social change. The loss of jobs – and changes in those that remain – will create the need for new compensatory mechanisms in the areas of wage policy and taxation.

Current discussions often seek to establish a relationship between the ‘guaranteed basic income’ and digitalisation. These discussions often centre on the affordability of such a basic income and whether it should carry conditions.

It is far beyond the role or the expertise of the authors of this survey to address this issue in detail. Our conviction, however, is that it is equally essential to address the impact of digitalisation on remuneration and to revise collective agreements in light of this impact.

If we are really expecting digitalisation to trigger social revolution at the scale that is often predicted then it is high time that we radically question and, if necessary, reorganise the entire system of work and remuneration.

The mechanisms for work, remuneration, taxation and distribution that we have today are the answer to dramatic problems that were dramatically, and rightly, tackled 100 to 200 years ago.

The answers to future problems in this area will be completely new. But which questions should we be asking today in order to have tomorrow’s answers ready on time?

One fact that can definitely be learnt from history is that a fair reward and acceptable working conditions are central factors for peaceful social development. If these are not achieved or if inequality and injustice grow then it is almost unavoidable that revolution and/or war will follow.

A significant factor here is the important position that work has come to enjoy in society. Those who work are perceived as valuable for society, unlike those who do not work. This mindset even goes so far as to suggest that voluntary work and a lot of work carried out on behalf of family and friends is not valued in a way commensurate with its social contribution. This also enhances this sense of imbalance.

In light of the upcoming digitalisation it is essential that we ask if paid work will and must continue to have the same importance that it does today. If the total amount of work falls, because so much is being done by machines and robots, should this not basically be seen as a positive social development?

The key issue will be to re-evaluate and find a new way of sharing out the financial resources available to society that, today, circulate in the form of total global wages. In addition to this, it will also be important to include those financial resources that are already available today, alongside wages, as remuneration for not working. This relationship between the remuneration for work and the remuneration for non-work is already a source of distortion and dissatisfaction in today's society.

Hence, it is strongly recommended that any study of digitalisation and its impact on society, the world of work and wages also seeks to “study and resolve” any equalities and grievances that are emerging in parallel, even if these have no causal relationship with or are in no way affected by digitalisation.

Quite apart from all these technological developments and the increasing use of digitalisation there remains the general question of how to create an attractive wage structure in the building sector. Three decisive factors here are knowledge, experience and engagement. Overriding all these, however, is the factor of design – the task of finding solutions to problems that arise.



It is essential to investigate and predict the extent to which the significance of these four factors will change, amongst themselves and overall, as a consequence of digitalisation.

Digitalisation will lead, for example, to the transfer of knowledge from the human brain to digital systems. Experience can be simulated digitally by AI, although this will never be useful without human input. Engagement will remain as central to success tomorrow as it is today – but in the digital age this will be the engagement of machines.

Design, however, will always require the guidance of human intelligence, whether this is in the form of innovation, creativity, organisational ability or motivation and assertiveness. Hence – we can assume that, in future, design will be the decisive factor in the remuneration of human beings because this cannot be replaced by digitalisation and automation.

This suggests the academic directions that should be taken by those looking for high qualifications that will be indispensable and valid over the long term. In this connection, however, it must also be pointed out that high qualifications do not automatically lead to higher wages. Accompanying socio-political measures such as the development of new wage structures must also be part of this area of investigation.

The relationship between the amount of work, remuneration, health and age will also be essential in the future. If we are to use the positive potential of demography and healthcare to boost the value creation process it will probably no longer be possible to maintain the currently widely accepted ‘basic formula’ whereby wages automatically rise with age. This will also necessitate a new approach to remuneration.

#### 8.1.4 The tax system

Taxes manage the distribution of financial resources amongst the members of society. They play a central role in creating a subjective and objective sense of fairness and satisfaction both in the population in general and amongst workers in particular.

Subsequent to our comments in the chapter on “wages” it is essential to point out that wages and taxation are communicating vessels.

Another question is the question of how we approach taxation – how we achieve the necessary social redistribution in order to help the weak while encouraging the strong to participate and demonstrate solidarity. The historically justified approach of taxing wages and income has been overtaken by more recent economic and technological developments. Value creation is shifting from people to machines. Income is being generated less by work and more by data-based algorithms. But these are rarely fairly taxed. From the point of view of the labourer this is highly relevant because the taxation of work carried out by humans makes human work proportionately more expensive than work carried out by machines.

A further distortion of tax policies is caused by the fact that digitalisation makes it possible to swiftly and almost intangibly shift work abroad. This means that large parts of the global value chain escape fair taxation. From the point of view of labourers this is highly relevant because it triggers labour migration, which is often against the interests of their own business location.

In the opinion of the authors of this survey, future taxation systems should have the following objectives:

- A reduction in the tax burden on human work
- The taxation of work by machines because this is replacing human work
- The introduction of fair taxation on financial transactions in order to avoid unjust distortion

### 8.1.5 Handling data

The ethical handling of data will be one of the greatest challenges of the future. On the one hand, consistent and complete data can bring great benefits for all of us while, on the other hand, this represents a great risk to our liberty. In the hospital of tomorrow everything will be captured by tracking and tracing technology



– and the same is true for the building site and, in a worst case scenario, for society as a whole. How do we protect ourselves from abuse?

The handling of data represents a completely new challenge for society and demands a concrete definition of ‘human rights’ in relationship to data. The challenge will be to establish a balance between the necessary and reasonable use of this data and the prevention of abuse. This balance has often been missing from previous rules. And such rules in other areas are sometimes missing completely or can lead to unnecessary costs and exaggerated restrictions.

Looking around the world there are currently three basic approaches to handling data and, in order to avoid being politically incorrect, we will leave it to the reader to decide the locations to which we are referring:

- **System 1** is unregulated and uncomplicated but accompanied by a “threatening” legal system in the sense that “the state governed by the rule of law establishes the rules but the population is unaware of when and how these will be applied”. And of course a state governed by the rule of law is also subject to the political change which could increase or reduce the level of this threat.
- **System 2** presses for very strong regulation or even overregulation, which in turn can often put a brake on the development of the society or the economy. The question arises of how strongly and how early digitalisation should be restricted by legal standards.
- **System 3** is, on the one hand, politically expansive but, on the other hand, repressive in terms of human rights and makes intense use of “social scoring”, which is designed to motivate and control but can also be seen as repressive. Digitalisation presents politicians with decisive tools for controlling society in all areas of life and work.

The general questions regarding the handling of data are diverse:

- Which data are recorded?
- What are they used for?
- Are all these data necessary?
- Who has access to them?
- For how long are they available?
- Who owns the data?
- Who is responsible for administering the data?
- Which data are considered to be “personal data”?



We come across “construction data” in a number of areas, whose data are also linked.

- Design and building data from the BIM survey of the existing to CAFM
- Process and production data in, for example, production, logistics and administration
- Data mining e.g. of existing buildings at the end of their lifecycle
- Personal data of particularly high relevance and sensitivity

Different people are responsible for managing data in different areas, e.g.:

- Building owners and clients, public and private
- Contractors, construction companies and other tradespeople, entrepreneurs and employers,
- Consultants, planners and other project participants
- Public agencies, statutory authorities, advocacy groups
- Individuals who are involved in the project

The ‘data managers’ who are most threatened and in need of protection are the members of this last group: the individuals who manage their own data. It is almost impossible to prevent their personal data being passed on to other data managers in other areas – including, of course, for purposes that are legitimate and in the interests of the project.

This subject alone brings us to an area of activity that is almost impossible to gauge and to manage. On the one hand, it is reasonable and, indeed, unavoidable that some personal data is accessed and used in the interests of the project, as mentioned above in the example of the use of patient data in hospitals. In this context, however, it is also often unreasonable to demand that data is anonymised because personal evaluation is often required.



Simple examples of this on the building site are timekeeping data or master data for individual workers, which are, by definition, personal data. On the other hand, it is precisely such personal data which are particularly prone to abuse when being handled by third-party data managers in combination with data from other areas.

Hence, we have to establish political, social and economic parameters that offer the best possible defence against the abuse of data and enable us to react effectively when such abuse occurs. Having said this, however, how can we also shape these political, social and economic parameters to ensure that we optimise the benefits of digitalisation and automation?

This debate begins with the recording of data on site. In future, workers on a digital building site will be confronted with comprehensive data capture, from the scan upon entering the site, via the digital recording of the progress of construction work to a wealth of machine-related data.

This recorded data will also enable us to derive further personal data – for example, by linking data generated by machines or tools with their operators. The ethical handling of personal data – and the laws governing the handling of data – will have a decisive impact upon how our society develops.

Such automatic linking of machine data and personal data already takes place in the manufacturing industry. Collective agreements often determine the rules governing this automatic data linkage.

In any case, the basic first step must be to define data ownership, which means that it must be made quite clear to the affected persons how their data will be used. Such an obligation to give information must be coupled with a guarantee of complete transparency. The individuals affected can then decide whether they agree to this further use of their personal data. Despite this, however, the impact of this for these individuals is still often impossible to assess.

The central question is whether the use of these personal data could also lead to a situation which puts the worker at a disadvantage.

There are several basic methods of protecting personal data:

- Anonymisation or the use of pseudonyms

- Aggregation
- Limiting access

In the first case, several anonymous data keys are used that permit general trends to be identified but not the personal data of an individual. In contrast, the aggregation of data permits individual data sets to be identified, but not assigned to a specific person.

A further method employed today is 'differential privacy'. Here, a sixth of all data is deliberately used incorrectly in the knowledge that, if 5/6 of statements are correct, reliable and informative conclusions can still be drawn.

In order to limit access, encryption algorithms can be used. Encryption and decryption technology in communication is already well advanced. In principle it would be possible to make very wide use of cryptographic processes, although the reality is that this is often prevented by the high costs involved.

There are, however, already practical examples of data that can only be jointly decrypted by management and workers' representatives.

It is thus quite possible that organisational solutions for limiting access could be found, although even these would not be able to offer a complete guarantee against circumvention and data abuse, especially as future developments bring unforeseen new challenges.

In any event, 'levels of security' are essential, as are socially agreed standards regarding which data may be stored where and to whom this data should be accessible and when. In terms of the relationship between the company and the worker in particular it is essential to determine who has access to which data concerning the other party. This requires a political consensus similar to a collective agreement. In other words, trade unions must be concerned in future not only with collective wage agreements but also collective information transparency agreements. In this scenario, the trade unions will have the opportunity to position themselves strongly as the data protection champions of the worker of the future.

It is in this context that we should consider the 'Baucard' (ISHAP chip card) discussed previously. This could enable monitoring to be employed to protect workers but also to protect business. Both sides should be interested in fighting against wage and social dumping.

The following clarifications are required in the case of such chip cards:

- Which details will be recorded?
- Where are the data stored?
- To whom are the data available?
- How transparent is the data in terms of working hours / contracts / health data, etc

Taking into account the international nature of the construction industry and the construction-related labour market it is important that any such regulation is at least Europe-wide, if not global.

Discussions of the digitalisation of building sites regularly turn to the subject of effective control. But which legal framework will enable which control bodies to oversee the impact of digitalisation on construction workers and which correction mechanisms are available when intervention is required? E.g.: labour inspectors, construction industry legislation (BauKG), 'site health & safety' officials etc.

Requirements and control mechanisms for the handling of data are to be specified in tenders and upon the award of building contracts – see Chapter 8.3.

The fact is that, in future, individuals and companies will be more transparent. This means that it is in the interest of both sides to develop WIN-WIN situations for both workers and employers.

### **8.1.6 Health and environment**

Digitalisation can bring particularly concrete benefits in these two areas. In particular, because the large amount of data that will be available to us in future will enable us to carry out new and comprehensive analyses and simulations of future developments.

Health and environment are two very closely related subjects. The first is concerned with the personal health of workers and the other with their surroundings, with the environmental conditions on the building



site that can have a major effect upon their health. This subject is closely related to the quality of work. Only when workers' health does not suffer can we talk about high quality jobs and working conditions.

However, just as in the above-mentioned case of the digitalisation of the health sector, the opposite side of the coin is the potential abuse of health-related data.

The following examples indicate potential practical relationships between digitalisation, health and the environment.

This is an area in which the comprehensive recording of data can be used to the benefit of workers: Information from sensors can be evaluated with the aim of reducing the negative effects of work. The impact of any activity on the health of a worker can be analysed and processes can be adapted accordingly.

The use of new technologies such as robots, drones and, in particular, exoskeletons can reduce the burden on workers. The two basic objectives of a) allowing robots to carry out exhausting, repetitive tasks and b) developing intelligent, mechanical and/or motorised

support systems can both have an extremely positive impact on workers' health. At the same time however, workers' representatives must ensure that these technologies are not used in such a way that workers end up working until they are exhausted or have to perform the same task for much longer. Rather, the objective of new technology must be to ensure that work is both safer and less exhausting.

A further emerging factor that we should consider is the appearance of new pathologies amongst building site personnel. Stress symptoms, which have previously generally been associated with managers or office workers, are increasingly prevalent on building sites. In part, however, this is also a result of the fact that 'being under pressure' is now a social norm: 'Performance' and 'self-optimisation' have become fundamental social processes over recent decades.

The fact that individual workers are more likely to be assigned individual packages of work (with individual targets) on the building site – another source of stress – is also a result of economic considerations. The size of teams is being reduced because workers have become more expensive. The better the training, the greater the personnel costs, as a result of which the number of workers on site is falling – in every area. At the same time, however, everyday tasks are becoming more complex. Routine jobs, of the sort that previously offered labourers some short relief are now carried out by IT or robots. This means that workers now have to concentrate intensely for 100% of their working time. In addition to this, the boundary between working time and leisure time continues to blur. The need to be permanently available makes it more difficult for the individual worker to define clear periods for undisturbed recuperation and, hence, for releasing stress.

The end result of all this can be burnout, but this is a long process. It could be preceded by, for example, an immunodeficiency, which might initially only lead to a harmless cold. However, as it has become more normal to react not by taking a rest but by continuing to work despite a mild illness, this can lead to more serious illness. Time off is particularly difficult to organise on building sites, with their tight timetables and general understaffing. This is a vicious circle for all involved.

As the tasks that have to be carried out on building sites move more in the direction of management tasks, this is bound to affect the role of building site workers. Here, it is important to consider that the requirement to carry out unaccustomed tasks in a digital environment can quickly lead to a feeling of overload. An unstructured flood of data can cause disorientation, which can lead to a sense of a loss of control and, in turn, stress.

In the wider socio-political debate it is fundamentally important to ensure that the value of the 'human being' as a resource is both recognised and economically appreciated. Companies must learn to deal with this resource carefully and respectfully – most particularly in a period in which we are constantly hearing

about the shortage of skilled workers and the potential use of robots. It should be recognised that human workers are a valuable economic good – specifically as a result of those qualities that distinguish them from robots – and that they represent an essential instrument that – properly employed – can guarantee the success of a construction project.

### 8.1.7 The image of construction work

‘The shortage of skilled workers’ is repeatedly cited as a key issue in the construction industry.

But one should also ask whether this shortage is partly a result of the nature of the discussion about construction-related professions.

How can enough people be convinced to choose these professions?

More generally, what makes a profession attractive?

Besides decent remuneration and the opportunity for self-fulfilment, work-life balance and the image of a profession undoubtedly play a key role.



It is essential to successfully position the profession of ‘building worker’ as a ‘high-tech’ profession. Increasing digitalisation means that this is unquestionably the case. The growing use of new technology is also banishing the image of the ‘dirty’ building site dominated by ‘hard work’.

The promotion of a different sort of work, of a new, modern, collaborative partnership in a skilled, solution-oriented atmosphere based on mutual respect in which an interesting ‘product’ – the building project – is created, can positively transform this image.

This will not only have a significant impact on the attractiveness of the profession of ‘building worker’ to the young, promising next generation of workers – especially, in greater numbers, women – but will also improve the position of the profession during wage negotiations and, hence, improve the general financial situation of the building worker.

It is essential that the industry succeeds in attracting the next generation of ‘millennium workers’ – the high potentials, who have grown up with iPhones and gaming consoles and enjoy a high level of affinity with technology. In this respect, one should also analyse the issue of ‘gamification’ in general – can we present individual tasks on the building site in such a way that they can be seen as ‘game-like’ and, hence, appeal to the ‘next generation’ of building workers?

Meanwhile, the building industry and building companies face another issue related to public perception. They have to present themselves in such a way that the entire sector is perceived as forward-looking, fair and ‘honest’. The responsibility for this lies not only with those who establish the political and legal parameters but also – primarily – with all companies and individuals who work on building sites.

## 8.2. Corporate and project processes

One cannot consider the fate of workers without considering the fate of the companies that they work for. Construction companies depend upon the success of their projects. Digitalisation will have a dramatic impact on corporate and project processes, which means that these are a significant area of investigation for this study.

### 8.2.1 Company size, technology and finances

It is often assumed that it will be easier for larger companies to react to the often cost-intensive transformation process brought by digitalisation than smaller ones. For a business location dominated by SMEs this is a vital issue. Those who take the opposite position usually argue that this revolution will generate lots of opportunities for small, creative and more agile companies, right down to the size of start-ups.



In reality, corporate structures in an age of increasing digitalisation will be determined by the degree of development of software products, the political desire to create or avoid monopolistic or oligopolistic structures and the emergence of models for remuneration which meet market needs.

The ability to optimally use often rapidly changing new technology will also be influential.

However, the most influential factor is the value of data, which

are extremely expensive to obtain, process and continuously update. If one owns data, one is in the position to intelligently, efficiently and exclusively offer all services in all project phases and dominate the entire value chain.

Hence, there is much reason to believe that large, international companies will be able to benefit the most from digitalisation.

If there is a political desire to maintain a long-term balance between larger and smaller companies and to very consciously support SMEs and start-ups, this will require intervention in terms of both economic policy and financial incentives.

### 8.2.2 Avoiding mistakes through early detection

If digitalisation is properly deployed in the construction process, it is possible to detect problems early in the digital twin of a building and, hence, solve these problems and save money. This requires cooperative, open interaction and a positive attitude to dealing with problems.

This will also require a cultural change within projects and companies as well as on the building site.

The identification of problems during the early development and design phases requires experience of the later constructional and operating phases. As a result of this there is a clear opportunity for experienced practitioners – construction workers – to become involved in earlier project phases.

Understanding that this vital know-how is present on the building site and paving the way to benefitting from this know-how requires both sides – developers and designers in the office as well as practitioners on site – to change their mindsets.

This could lead to the creation of new job profiles or types of assignments. But the remuneration of this work will require an innovative approach. Such remuneration will demand incentives – but how can incentives be introduced if these escape the traditional definitions of today's contracts, specifications and project phases? This is a subject for ProCS in Chapters 8.3 and 9.3.

### 8.2.3 Designing and building with elements

Digital twins are created according to the “element method”. BIM “thinks” in elements and systems. It is obvious that industry will digitalise “its” elements and offer these to planners. Such industrial processes and products, offered in the form of digital ‘standard libraries’, will assert themselves at both the digital and the factual level right through to the building site.

How will this affect competition? How will supervisors and forepersons position themselves in this new world of work and business? Will they be involved and invited to contribute their practical experience in the permanent optimisation of these standard products. They should, for they are often the only ones able to comment on the practical advantages or disadvantages of a proposed solution when it is exposed to the realities of installation on site, of wind and weather.



Josef Muchitsch (left), GBH President, Austria and Chair of the BWI Ad Hoc Technical Working Group on Future of Work with Ambet Yuson (right), General Secretary of BWI

This is another area of activity that is worth thinking about.

This is another area of activity that future generations of practitioners could prepare for.

#### **8.2.4 The transfer of building work to production facilities**

A further structural change that is widely expected is the increasing prefabrication of elements in controlled 'factory' conditions. The building site will 'only' be a place in which prefabricated elements are 'assembled' into buildings – as has been the case with steel building since the beginning.

The expected impact of this on the world of work is that new jobs will be created in the areas of production and prefabrication. However, these jobs will also require digital know-how and experience and knowledge of automated production processes.

On the building site, the move towards 'assembling' buildings will also require other forms of know-how. Much more stringent requirements in terms of tolerances will lead to new ways of working and these will also demand 'field experience' and technical expertise regarding assembly methods.

#### **8.2.5 New business models**

One general expectation of data networking is that previous boundaries between business models will be called into question. Existing companies will expand their existing business models further along the value chain while new business models (and companies) will also emerge.

A further potential development is the emergence of companies who will provide building-related services that remain exclusively digital. Such companies will require a minimum of trained and experienced professionals.

Striking examples of such business models triggered by digitalisation in other branches include UBER.

Returning to real, rather than virtual, executing companies, however, the authors of a number of sources cited in this study fear that there will be an increased division between companies with highly qualified personnel and proven management expertise and companies whose role is to supply lower-skilled workers.

Workers in these latter companies will then be lower paid, less protected and more easily interchangeable as a result of which it will be much harder for them to fight to improve their position.

This highlights a fundamental danger facing the industry: A growth in the number of 'digital' companies with intransparent structures designed to circumvent regulations – including labour regulations. (Cf. 77, 78 TUAC Policy Recommendations)

#### **8.2.6 Humans and 'cyber-physical systems'**

New technologies such as robots, drones, 3D printers and machines controlled by sensors that communicate with each other via the IoT will move onto the building site. This will also lead to changes in corporate processes – both during the project phase and on site.

For workers on building sites this could lead to either the development of new skills in preparing and managing these processes and controlling operations and troubleshooting on site – or the relegation of such workers to the "lower-skilled" roles of assisting these machines.

Care will have to be taken in developing these technologies in order to ensure that the automation process minimises the need for such "lower-skilled" roles. In other words, resources must be invested in both improving the quality of work and avoiding deskilling.



Steering this change in the right direction will also require incentives – simply banning negative developments will not be enough. This is another example of a cross-border international phenomenon upon which domestic markets will only have limited influence.

Hence, when considering use-cases of these new technologies, becoming involved in research cooperation could offer an opportunity for interested organisations to both gather information and steer developments. Major international projects with global concerns could provide an opportunity for this.

On the other hand, one cannot deny that lower-skilled work is also an opportunity for some, for whom it would otherwise be difficult to find a dignified position in the world of work – but the conditions must be fair.

### 8.2.7 The organisation of work

The organisation of work is determined by three factors, two of these factors apply fully today and the third will become increasingly important in the future. All three are dependent upon management decisions and affect companies and projects at every level.

- The organisation of the company – what will be the interfaces with other departments and organisational units?
- The organisation of the work – how will the work be organised and/or shared out, centrally or decentrally, team-oriented or hierarchical?
- The scale of automation – what will become automated?

There are basically two approaches to the organisation of work:

- Tasks are strongly based on the division of labour with individual steps being executed by lower-skilled workers; Each unit is controlled and led by higher-qualified workers
- Teamwork within a functional, flexible organisation in which workers with different qualifications and skills work together in teams of more-or-less equal partners

A special form is the swarm organisation. This is mentioned here because the authors of a number of sources cited in this study predict or recommend that this form will or should be adopted in the future for intensive digitally supported processes.

*The swarm organisation “is characterised by a loose network of qualified and equal workers”, simple activities that require few skills are largely automated. Individual workers do not have fixed and repetitive tasks. Rather, the entire collective body of workers is flexible and self-organising and reacts to each individual situation within the context of its shared operational objectives (Hirsch-Kreinsen 2015, p. 18).*

*In the contrasting scenario (the polarised organisation) the focus of this polarisation is qualifications, which have become more important as a result of the reduction in the number of medium-grade workers. The organisation of work is simplified down to the clear division of this work between the “decision-making level” and the “executing level”. The decision-making level is occupied by highly-qualified technical specialists and the executing level by lower-qualified workers (ibid: 19f.). While the highly-qualified are responsible for controlling plant and production management, the low-qualified perform simple manual tasks and carry out standardised monitoring and controlling activities.*

*From 34, Forba, Source: Hirsch-Kreinsen 2014b*

The successful organisation of teams requires not only the involvement of wider processes in the field of group dynamics but also the time and experience to shape these processes and, hence, to lead these teams. The subject of responsibility must be clearly communicated and shared by each participant. For a company, this naturally requires a certain amount of time to adapt. If the role of ‘governance’ is not taken seriously, it is very easy to ‘slip back’ by surrendering this new sense of responsibility, abandoning these newly agreed ‘commitments’ and developing a ‘blame culture’.



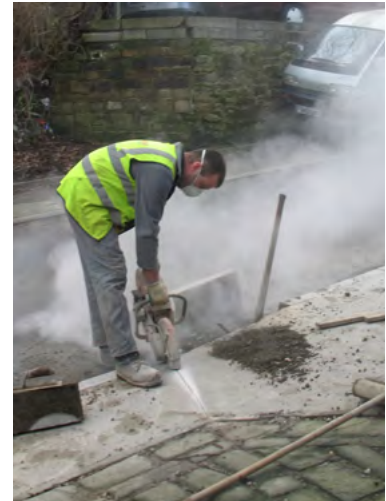


According to 54

*Hierarchies can be dismantled. Everything can be discussed and decided in an open space. But this doesn't mean that strong personalities don't continue to lead in a "character-driven, hierarchical" manner.*

The extent to which such alternative forms of organisation could be applicable to the construction industry with its traditional, strongly differentiated trades and professions remains open. However, the fact that similar developments are occurring in the IT and manufacturing industries suggests that they should not be discounted and should, rather, be addressed seriously.

A further subject related to the organisation of work is physical distance. Building will remain a location-related activity, but new media such as the Internet, WhatsApp and technologies like robots and drones mean that decision-making processes must largely no longer be location-specific



A concluding question regarding the future organisation of work could be as follows:

Why shouldn't it be possible for a couple of construction workers to get together with a couple of digitalisation experts and begin, in the form of a start-up, to offer their practical experience in the areas of the preparation, organisation and quality of work, coupled with their expertise in digitalisation, on the market?

We should work on such – even disruptive – models.

Or, putting it better: we should make it possible for them to emerge.

They should occur to somebody. This often has little to do with work. That follows later.

### **8.3. ProCS – Procurement (tenders/tender awards), contract & settlement**

At the end of the day everything that happens – or should change – on site, happens because of tenders, tender awards and contracts. And in order to ensure that all this happens successfully and fairly for everyone the contract is to be equitably regulated by the settlement process.

The tender and award process establishes the basic direction that will determine whether a project is completed successfully. If one wants to improve the public image of the construction industry one should address this area of ProCS. The significance of ProCS for the quality of construction processes and the public image of the construction industry has nothing to do with digitalisation. But one could see digitalisation as an opportunity in this area.

ProCS is thus correctly seen as a key area for determining the success or otherwise of a building project. It covers the central processes, technology, law, economics and controls all qualities (performance, work, environment, health, security, the remuneration of companies and workers).

ProCS will change markedly under the influence of digitalisation (cf. source 29). Just like many legal regulations it will have to be adapted to meet the needs of a digitally managed project world (cf. source 02). Data protection, sovereignty, security and use as well as access privileges are all subjects that are currently under discussion but which have yet to be satisfactorily resolved.

#### **8.3.1 Fair procurement**

Tenders and contracts will have to be completely newly regulated. These rules will govern the relationships between companies but also affect the rights and obligations of workers.

The subject will initially be regulated by procurement law at both the national and European levels. But what else will have to be regulated in a new way due to the demands of digitalisation in order to meet the expectations of construction workers with regards to the ProCS process?



“Fair procurement” is already a subject that is being practically discussed in the industry, even if this discussion is still more focussed on the principle itself than its concrete, practical implementation.

ProCS determines the quality and the remuneration of work. The contractual pressure on a company expresses itself by passing on this pressure to the company’s workers. Fair procurement must also be fair for workers. The way in which the impact of fair procurement can really be passed on from a client to a contractor and then on to the contractors’ workers requires further research in both theory and practice.

Larger building projects and also, today, some smaller ones take the form of multi-element value chains that also often include international suppliers and workers.

This means that cross-border regulation will often be necessary in order to ensure that domestic projects are managed with the required social standards.

### 8.3.2 Data handling requirements

The approach to dealing with data and digital processes is to be addressed early in every project, e.g. during the project development phase, architectural competition and appointment of designers and consultants. Decisions that are not taken at this point or are taken wrongly will have a negative impact on all project participants – including construction workers.

The EIR, the Employer Information Requirements, already regulate the handling of data in BIM projects. On the basis of this, the project team draws up the BEP, the BIM Execution Plan. This document focusses on BIM.

Taking this further, legal rules and tried and tested practices should be developed for governing the handling of data at all levels and for all aspects of digitalisation – not just for BIM.

From the perspective of this study, the central question remains the impact of such regulation on workers. Given that construction projects, unlike in the manufacturing industry, are based not on infinitely repetitive processes but “unique” projects in constantly changing configurations other mechanisms of action are required. ProCS is a key mechanism of action.

### 8.3.3 Forms of involvement of companies and workers

The “uniqueness” of projects is an invitation to constantly test new approaches – including approaches to circumventing obstacles. The proximity of and interrelationship between economic regions with very different systems, increased international mobility (labour migration) and the growing formation of cross-border value chains is having both positive and negative results.

It is not uncommon for economically less costly and more competitive solutions to have effects that are also anti-social and indefensible from a human perspective.

Digitalisation and automation will transform the construction process and nudge it in the direction of standardisation and repetitiveness, mirroring changes that have already taken place in manufacturing industry. Regarding ProCS, it will be necessary, to a certain extent, to develop new tender and contract models that completely reimagine procurement structures and address and fairly reorganise these newly emerging production processes from the point of view of construction workers in terms of the quality of work and remuneration.



Potential practical illustrations of the above complex and theoretical statements can be derived from the examples and scenarios set out in Chapters 3-6 of this study.

- How can we create tender conditions that regulate the rights of workers who work intensely with machines (“treat the robot”)?
- Which legal rules are required in order to regulate tenders and contracts in a way that is practical, positive and makes them hard to circumvent?

- How can collective agreements be drawn up and implemented in the future? Which new requirements will emerge from digitalisation? Can data handling be regulated by collective agreements?
- How can we manage the way in which international mechanisms affect the labour market for building projects?
- Will digitalisation drive the growth of badly-paid, unqualified routine work and how can this be countered?

#### **8.3.4 ProCS and economic development**

Last but not least, ProCS is also decisive for the development of the economic structures of any business location. If we want to retain and expand our small-scale, decentralised, modestly structured, person-related and highly qualified form of business then digitalisation presents us with the means of doing this. Non location-specific communication, decentralised home working, new forms of (sometimes international) networking and new entrepreneurial approaches are all emerging.

In some countries such as Sweden repair and manual work are in demand again. What can the construction industry learn from this? How could this affect the value chain and material cycle? Can and should the construction industry become more local again and how could we (and do we want to) respond to this as we reshape ProCS and the wider legal framework?

Developments in this area will be particularly dependent upon the public clients who dominate the construction industry. These act to a large extent in line with political requirements, which can be very wise or quite the opposite. It is essential that ongoing developments are dealt with wisely.

#### **8.3.5 The costs and long-term benefits for the economy and labour**

We are constantly asked “what should it cost”?

Quality for the economy, quality of work, quality in infrastructure and essential services cost money and must be worth something to us.

The speedy expansion of the foundations of digitalisation, the essential infrastructure, is another relevant subject here. Long-term investments are necessary, which will be subject to the development of ProCS. But too often the focus is on short-term successes designed to bear fruit before the end of the next electoral cycle. In the long term these cost more and do less for the indivisible, intertwined development of the economy and labour.

Long-term investments don't just create short-term jobs. They also underpin the business location and competitiveness in the long term. In the context of ProCS, the task is often to prepare and procure long-term projects, to address any related obstacles and to involve domestic companies and workers.

### **8.4. Tools and the interoperability of software solutions**

#### **8.4.1 Data protection and personal security**

From the workers' perspective, this issue addresses

- the impact on the private sphere in terms of, for example, data protection and security
- The concrete impact on the work and the working context of the individual

The effects of digitalisation at the social level (Chapter 8.1) and corporate and project (Chapter 8.2) levels are only indirectly addressed here in terms of their impact on individuals.

With regard to data protection and personal security, the issue here is how we handle the personal data that will undoubtedly be collected.

- Handled positively, these can improve efficiency, the quality of work, security, health, etc.
- Handled negatively, these can lead to monitoring, control and, at the extreme, totalitarianism

General solutions to this issue are addressed in the areas of investigation 7.3

A key issue raised by digitalisation in companies is how the recording and distribution of and access to data are organised. Data are very valuable – in both economic and ethical terms – to both companies and individuals.

This leads to a natural area of contention in which it is essential that we maintain an equilibrium. Both sides are advised to carefully prepare and address these issues both theoretically and politically and to clearly identify what the other side demands and is unable to accept.

#### 8.4.2 Data management and networks

The impact of digitalisation on both of the above – on individual work and personal security – will be decisively influenced by the way in which data management and networks are organised within companies and projects.

While it is still common today to widely distribute large quantities of data we must address the question of how this data is most logically structured in order to achieve the desired efficiency in project processes. This requires the concrete analysis of who really needs which data and in which form?

This question cannot be addressed in isolation at the departmental level. It requires an overview of the wider situation in order to find an overall optimum.

At the level of the building site, data-related processes should be organised in such a way that information (data and documents such as operating instructions) can be easily found and processed by those who need them. If the flow of data is regulated accordingly and the use of apps and other software adequately designed to be user-friendly and individually adapted to the special needs of each project then the level of acceptance of digitalisation will rise significantly.

*At the end of the day, information management is the key overarching subject.*

*The increasing digitalisation of design, execution monitoring, operational data and communications, etc. represent a huge challenge for the project team in terms of the structuring of all this data. Different stages of development demand different data hierarchies, but these must be combinable in order to permit the comprehensive use and referencing of data.*

*Only the consistent use of identical names for identical elements and the clear organisation of the necessary data hierarchies will allow this data to be processed by different softwares for different purposes.*

*From 14*

In future, project management will increasingly become ‘information management’. This will apply to all leading roles, including the foreperson.

The essential objective here will be to create a corporate culture in which the readiness to pass on information and the courage to be as transparent as necessary are automatic. This also demands that workers are able to offer/take criticism positively and to deal constructively with problems.

#### 8.4.3 Data storage and data security

Private experience teaches us about how carelessly personal data is handled in social networks. Professional experience of the trend towards cloud solutions often teaches us about how such solutions can leave us open to external influences.

But there are countertrends, especially amongst young people who are aware of such problems.

Decisions made in the next few years will determine how different societies, national economies and international companies position themselves in this area. This will have a huge impact.

We also suggest that there is a new role here for workers’ representatives at the national, European and international levels. This is an area in which value systems are currently being created or changed.

#### 8.4.4 Data and markets

It is a fact that, in future, data will largely dictate the market and trigger market forces that small economies and smaller companies will not be able to withstand. Data and money are closely related – as is always the case with such valuable raw materials. And, as history always shows us, securing access to this valuable raw material will be a central objective of all economic players and seekers of power.

The costliest and, hence, determining production factors of the first industrial revolution were capital and raw materials. Will the costliest and, hence, determining production factors of tomorrow be data and the hi-tech software and hardware products required to evaluate this data and use it on the market?

At all events - digital data are becoming important merchandise.

#### **Analogy**

In future, data will play a similar role to that previously played by raw materials such as coal, oil and rare minerals. If one considers the political and economic power unleashed in the past few centuries in order to guarantee access to raw materials one develops a different way of looking at the future.

Both of these comparative analogies in which data is seen as the “determining raw material and market factor of the future” also permit analogies to be drawn up in terms of the impact on workers.

What was the position of workers when capital and raw materials were concentrated in the hands of a few owners?

Which mechanisms led to positive change?

Which negative developments had to be overcome, and how?

What is the impact of regulation? Over the short, medium and long terms?

How far should this regulation go?

Is there not a need for much more fundamental transformational processes?

Is it not essential to take positive advantage of market processes?

How can we affect these?

Can digitalisation help us to do this?

Perhaps it will enable us to introduce control loops about which we have not yet thought.

Does this not present a new role or direction for workers' representatives?

#### **8.4.5 Data interfaces, flexibility and interoperability**

Data interfaces and interoperability play a decisive role here. These will shape the way in which digital tools are used.

While some will strive for monopoly power and centralism, others will fight for openness, flexibility and interoperability.

#### **Analogy**

Microsoft and Apple have successfully imposed two systems globally, one of which defines the global standard. It is precisely this that enables people all over the world to communicate without difficulty. One can be highly critical of monopolies but one also has to admit that these can have some positive effects.

In this context it is essential that global users still have enough market power to be able to positively influence the ongoing development of this software.

In the field of BIM, two worlds are on a collision course as we write: Open and Closed BIM, represented by different software companies, construction cultures and advocacy groups. Considering the necessary market power it is quite unclear which system will prevail.



From the perspective of the authors of this study a broad range of suppliers would be more likely to promote the speedy and flexible development that would take the most advantage of the broad potential in this area while solving detailed problems with the right level of engagement. This would permit the quick development of apps that can be flexibly adapted in line with individual requirements and increase the scope for finding IT solutions. However, decisive criteria for the development of a meaningful range of usable software solutions are:

- Open connections (APIs) between softwares in order to permit bi-directional data exchange
- The meaningful standardisation of the data format
- The flexible and effective management of data interfaces within the software landscape of a company and the given building project (for the project itself / between the project partners)

It is important to avoid insular solutions that operate in isolation. These lead to additional data transfer costs and the advantages of working with information in 'real time' could be lost.

*It will take some time before there is a software product that centrally covers all possible applications. Indeed, the question is whether this would be a desirable outcome for the construction industry anyway.*

*It is clear that the long-term vision of a continuous data chain in the building industry requires that the various data worlds of digital planning, ERPs and logistics management must grow together and the need to use different software applications should be minimised.*

*However, the advantage of a more fragmented IT landscape is that this is more conducive to the ongoing development of highly specialist expert software (in such areas as structural calculation, geometrical optimisation, etc.).*

*Decisive factors include the development of intelligent interfaces between applications and the networking of the available data.*

*It is of course impossible to imagine that all the technical and process-related problems facing current planning and execution processes could be resolved by the introduction of a new software. The superficial presentation of models without the ability to substantially alter the process will also not improve the construction process: Unfortunately, the digitalisation of a poor process can only lead to a poor digital process.*

*From 14*

#### **8.4.6 Software development and digital infrastructure**

In any event, effective digitalisation demands software that is developed via a process in which software companies and the construction sector work closely together. And this process should place more emphasis on constructional expertise than software production.

In other words, software should be adapted to the needs of building and not the vice versa.

In order to achieve this, it is essential to create market power and to pool interests. This is why it is repeatedly said that European demands (e.g. in terms of working culture and quality) must be met and that those European regions who share such demands must work together in order to counter other market powers and pooled interests at the global scale.

The position of workers is only a good one when their working environment is being maintained or developed positively. This requires the right social and economic policies as well as an ethical approach to digitalisation.

Successful digitalisation requires a digital infrastructure. This creates the platform for extensive, economic and flexible development at the level of both companies and individual jobs.

Digital infrastructure represents a key investment in the future and creates both short and long-term jobs. Organised decentrally, it encourages the creation of regional structures, which can counter the ongoing concentration of people in major conurbations and the depletion and depopulation of remote regions.

Extending digitalisation to the countryside can do much to maintain valuable jobs that are already located there. In contrast with the immobility of major industries, digitalisation is, per se, a decentralised phenomenon. Understanding and encouraging construction and digitalisation as motors of local economies can represent an important boost for small-scaled economic regions.

### 8.4.7 Possible developments and considerations

A broad range of projects of cooperation with software experts and companies will also mean that a broad range of solutions can be developed and that the existing creativity and problem-solving ability of both sides is fully used.

There is a direct connection between the development of new software and software costs. Will the big players impose their expensive products on the market or will we work in a more diversified software landscape with a range of competing products with open interfaces? 'Closed BIM' with isolated, expensive software or open BIM, with easily 'dockable' special solutions.

A key issue will be the extent to which self-steering processes can be reasonably implemented. It is basically conceivable that robots will be controlled from the control room and (virtually) nobody will be found on the building site any more. But people will still be required to control the automated processes and robots and ensure that these function steadily as well as to interpret the resulting data and use these as a basis for making decisions in such a highly complex environment.



This will have an impact on jobs at every level of qualification. It is to be expected that complexity will tend to increase. However, the location of the interface between human work and artificial intelligence in the world of automation depends upon how work is organised. The storage of and access to information mean that knowledge, expertise and experience will be increasingly replaced by software.

However, work that requires the ability to take a broad overview and to comprehensively assess a complex situation and react accordingly, and quickly, will continue to be more effectively carried out by human rather than artificial intelligence.

*Mention can be made of the following tasks that will make certain professions more resistant to being replaced:*

*“complex perception and manipulation tasks, creative intelligence tasks, and social intelligence tasks”*

*The professions that are most strongly threatened by automation are unskilled workers, craftspeople, machine operators and people in service occupations. These areas all suggest a moderate or high likelihood of automation.*

*In the engineering sector, attention should be drawn to the great significance of creative intelligence for the work of the engineer. Pure knowledge-based work will disappear but design work will remain (Chapter V, p41).*

*In the view of the authors, “building work” will also offer a relatively high proportion of creative tasks in future in comparison with other sectors and should thus be addressed more specifically.*

*The résumé of the Oxford study, which suggests that digitalisation will replace low-qualified and lowly-paid work while highly-qualified and well-paid jobs will tend not to be replaced (Chapter VI, p.45), should be examined specifically for the construction industry with all its trades, professions and artisanal structures, which could well remain significant in the future.*

*From 38*

## 8.5. Research and development

Three measures recommended in the Roadmap 42 are also valid for this study

### 8.5.1 National and international research plan

The drawing up of a national research plan for the digitalisation of design, building and operation in Austria is urgently recommended. This should incorporate the research interests of federal, provincial and municipal authorities. Strengths should be pooled by defining concrete research focuses for each individual research institution, establishing priorities and initiating targeted research programmes. The duplication of work and research gaps should be avoided. These national research activities should be integrated into the international research landscape.

### 8.5.2 Pilot projects and sample applications

The practical testing of innovative products and processes is indispensable if digital construction projects are to be both technically and economically sustainable. These should be thoroughly researched as soon as practical in the form of pilot projects and sample applications and then tested to see if they can be used in practice. Essential features of such testing include a results-oriented methodology, the open exchange of findings and experience and the broad sharing of the results. As in the case of the research activities, these pilot projects and sample applications must be coordinated both nationally and internationally in order to prevent the duplication of work and opening up of research gaps.

### 8.5.3 Scientists and practitioners

Digitalisation is advancing at great speed and will continue to be an area of constant change for many years, right across the globe. In order to be able to derive concrete research results from the cooperation between scientists and practitioners there is a need for research and pilot projects that can be limited in terms of both content and timetable. Individual, clearly-defined research questions should be answered on the basis of manageable and relatively simple tasks. This applies in particular to scientifically-accompanied pilot projects, which address clear practice-based research tasks on a case-by-case basis.

## 8.6. Education and training

Here, the discussion of the role of education and training must be restricted to the focal area of the study: to the preparation of supervisors, forepersons and labourers for the upcoming digitalisation.

Hence, the issue is the professional education and ongoing training of construction workers, joiners and other related professions.

We should make the logical distinction between

- Education: initial education at school and during an apprenticeship as well as all other new forms of vocational education
- Training: life-long learning in fast-moving times, in and close to the professional context
- Retraining measures for individuals who have to prepare themselves for new job profiles

It must be emphasized that a high level of education with a good generalist base and flexible practice profile meets the right conditions for adapting to changing circumstances. Curricula and training profiles and programmes must also be continually adapted in line with these circumstances.

The questions will be

- How can all sections of the population receive a suitable, up-to-date education?
- What does an up-to-date education look like? How digital should it be?
- Should choices for the future not be taken at a much earlier stage of education? At what age?
- How can one differentiate education so that it doesn't become a levelling-out exercise?
- How can one use digitalisation in education in order to prepare the educated for digitalisation?
- How can we persuade young people to choose a "construction-joinery-work" education?
- How can young people and older people receive targeted educations?
- How can we persuade young people to help to educate older people?

A decisive success factor for apprenticeships and education is to persuade the best possible candidates to become apprentices and to reward them properly in terms of both remuneration and recognition.

### **8.6.1 Digital and analogue education**

It should not be our objective to give everyone a detailed digital education. Young people already bring to the table most things that they need in this respect. Older people must constantly be made practically familiar with the latest developments. They must be able to perform adequately in their profession as users of software and hardware.

It should certainly be our target to give people every sort of skill that they require in order to:

- Basically understand processes and process management
- Continuously expand their expertise and experience
- Be able to use digital tools and digital processes at a practical level
- Be able to constantly adapt to changing conditions

In any event, this education and training should not focus exclusively on software skills or digital know-how but must also particularly seek to strengthen 'non-digital' abilities. These could include the following skills:

- Good ability to think in 3D
- An understanding of process workflows and interdependencies; It is essential that process knowledge is retained
- A relationship with the reality of the building site
- The ability to critically question information – rather than 'switching the brain off' and blindly trusting all the data in the digital space
- Keeping 'control' of the system rather than becoming its 'slave'
- Understanding that 'cooperation' is a key success factor: this must be part of the training plan.

The possibility that ongoing digitalisation could lead to the loss of traditional skills, knowledge and experience is recognised as a significant danger: Simple examples of this are mental arithmetic and handwriting. In a more professional context, this danger extends to losing the sense for the job. This requires making assessments based on common sense, having a (gut) feeling of what works and what doesn't, what will stand up and what not, etc.

How can our education get across the message that:

- we must be able to assess, think through and decide with our own brain
- we must be able to sense and decide on the basis of our own feelings and experience
- we must be able to get involved, directly and uncomplicatedly, without always turn to IT for help

Or is this assessment completely false and will machines and AI be able to do and solve everything for us? We don't think so.

### **8.6.2 Surveying and realigning the education on offer**

Where there is not already an adequate overview the current educational opportunities must be thoroughly surveyed. This exercise must include foreign institutions, in particular across the German-speaking Region but also beyond, given the generally widespread understanding of English.

Curricula must be adapted for, for example

- Apprentice training, vocational schools
- The training of skilled workers
- Schools for supervisors and construction managers

### **8.6.3 An apprenticeship in "digital site know-how"**

Apprenticeships and vocational schools should develop a curriculum for this new job profile: a course that combines previous material with the new digital demands. Such new developments are to be undertaken in close contact with construction companies and the construction sector and, in this case in particular, with the software and construction machinery industries. They know not only the latest market and technological developments but also the needs of trainees.



**Analogy:**

In 1920, drivers and mechanics had to know how cars worked because they often didn't; this isn't necessary today because cars have become more reliable; and if it doesn't work today a mechanic also often isn't enough anyway – an electrical expert or software engineer is needed. Until 1970, cars were purely mechanical-electrical pieces of equipment. Today they are computers with motors and wheels. If we deliver a car to be serviced the car itself reports what the problem is and how it should be dealt with.

**8.6.4 Languages and soft skills**

Despite the broad range of digital translation aids, language skills will remain extremely valuable in the future. English will be indispensable in communication, information and research, technical texts, descriptions and operating instruction, etc. In Europe, this could apply to other European languages, especially in terms of working on building sites. On international building sites other local or global languages could also be important, especially for managing or communicating with workers.

“Soft skills” are also becoming increasingly more important. More and more people are involved in organisation and communication and have to adapt and react more and more quickly. Linear working is being replaced by team working. Human relationships are becoming increasingly decisive as a success factor. This is increasingly true for supervisors and forepersons.

Negotiation is no longer the reserve of top management. The ability to critically question, recognise and safeguard one's own interests is expected at every level.

In the future we will also be expected to understand what machines are saying to us and how. Even more than this we will be expected to set machines up so that they not only do – but also tell us – the right thing.

Putting it provocatively, in the future we will have to master not only managing people but managing – and communicating with – robots.

**8.6.5 ‘On the job’ training**

It can be assumed that there will be more “on the job” training in the future, in the place of training that replaces or is additional to “real work”. This trend can already be identified amongst today's students, who spend time while they are still studying or for several years afterwards first becoming familiar with the real demands of professional practice. The same will apply in the future to supervisors, forepersons and labourers.

One reason for this is the fact that learning that is integrated into the everyday working reality is highly effective and, hence, has a higher likelihood of being applied later than learning acquired in a one-off training session away from the reality of the workplace. Another reason is the recognition that there are many skills that are difficult to pass on in an abstract classroom situation. Only by performing these together with experienced workers or by experiencing the demands of the entire development process first hand will there be a lasting learning effect.

In both cases, it is easy to conclude that 'on the job training' is more efficient because it requires no additional time. This, however, is a misunderstanding. It may well be true that it involves less 'pure training time far away from the workplace', but the organisation of high-quality and sustainable teaching demands the coordination and testing of appropriate training concepts. This requires adequate preparation time in order to develop these concepts and implement a structured 'lessons-learnt' process in a company. A training structure must be established that leaves enough space for operational work while also allowing time for learners to absorb and repeat the task that they have learnt.

This requires new processes and a new understanding on both sides, amongst companies and their employees, which accepts not only the amount of time required for the training but also the associated costs. Companies must very consciously create the conditions for this to happen.

Workers must get the sense that they are learning something concrete that they can also demonstrate – this satisfies their sense of ambition as well as increasing their 'market value'. One could also imagine certifying such training for both the employee and the company – this could be effective in attracting skilled workers to certain companies.

*Hence, should people just learn what they need in order to do their job or should they be introduced to a wider range of data and context-sensitive information, which is carefully drawn from real-life situations and expertise and which can influence the way they perform that job? The attempt to draw up and systematise such information for the purposes of learning and working threatens to be an underrated barrier in the development of "Industry 4.0", which will possibly only reveal itself as more complex technologies are introduced. Reserves of expertise, which we risk neglecting or losing altogether due to a premature reliance on the benefits of automation, will then no longer be available in order to bridge the gap between the development of technology and our skills base.*

*If the expertise required to operate "Industry 4.0" systems is to be taught in small-scale vocational modules, these modules could become so virtual und standardised that they do more to hinder than to facilitate the development of practical experience-based knowledge and the ability to investigate and to competently manage and direct complex, data-intensive processes.*

*From 33*

A further aspect of 'on-the-job training' is, hence, the focus on process knowledge. Know-how about complex processes and the technologies behind these processes can only come from learning that is integrated in the working process. Workers with such process know-how, an understanding of interrelationships and the ability not to lose sight of the 'big picture' are extremely valuable to a company. Skilled workers with such qualifications increase the resilience of a company.

Hence, companies that train and invest in such a way are facing a WIN-WIN situation. But this must be a long-term policy. Regarding the issue of the organisation of work in particular it should be noted carefully that knowledge can be lost very quickly if individuals do not meet the requirements for such forms of learning. Hence, the issue is not the acquisition but the retention of such process knowledge.

*See also 33:*

*Hence, the process knowledge that is often seen as an essential qualification is not easy to either acquire or retain in highly-complex, closely integrated processes that involve machine-to-machine communication.*

This means that 'life-long' learning must be more than an empty buzzword – companies and individuals must make a commitment to this objective: via the appropriate corporate structure and the curiosity and willingness to learn of their workers.

And, according to 54

It can basically be determined that the educational system is moving radically away from "learning about things" to "learning how to learn".

## 9. Recommendations for action

### 9.1. Political, social and legal parameters

#### 9.1.1 Concentrating energies

We have to join forces at the domestic, European and international levels because the effects of digitalisation are not held back by national borders and the global interconnection of trade and value creation mean that we are multilaterally dependent upon each other.

#### 9.1.2 Labour and business

If future measures are to succeed it is essential that they overcome the apparent conflict between the interests of labour and those of business in order to bring about WIN-WIN situations: Social interest groups must accept that measures have to make economic sense while business must accept that the economy is far from being the only criterion.

#### 9.1.3 Social consensus

We must find a completely new consensus between politics, society and business if we are to deal with the upcoming challenges. Major social upheaval runs the risk of encouraging radicalisation. This means that the permanent search for social consensus – for democratically meaningful solutions that respect a range of policy positions – is politically decisive. We must develop a new ‘we’, based on transparency and trust. Compromise in itself is not a bad thing but, rather, a result of balancing interests.

#### 9.1.4 Intergenerational cooperation

Digitalisation is encouraging a new form of intergenerational cooperation like no subject ever before. This could lead to a long-term, mutually beneficial reconciliation between the technological tranquility of the young and the often sceptical approach of the old.

#### 9.1.5 Interdisciplinary exchange

The demands for concentrating energies and interdisciplinarity create a need for suitable platforms and sustainable exchange mechanisms designed to control the fast-paced and often disruptive development of the digital transformation.

#### 9.1.6 Presenting subjects positively

Success also depends upon the positive presentation and perception of the inevitable digitalisation. It is equally important to ensure that the construction industry has a positive public image.

#### 9.1.7 Creation of social networks

Safety mechanisms for construction workers are needed – in parallel with and coordinated with other industrial sectors and politics. Restructuring and retraining measures and a range of other safety nets, financial and otherwise, are needed in order to soften the blows caused by transformations in some professions.

#### 9.1.8 Future models of income and taxation

These must be seriously considered at the domestic, European and international levels, in order to respond to new production conditions and labour forms. A guaranteed or non-guaranteed basic income should be examined in detail. The relationship between income, taxation and economic and social demands should be examined and adapted to the changed environment.

### Handling data and data ethics

A legal framework for handling data must be created and the practical implementation of this framework controlled. It is vital not to lose sight of the developing relationship between transparency, responsibility and freedom both as a social issue in the broadest sense and with a special focus on construction work, supervisors, forepersons, labourers and future employment regulations and other collective agreements.





#### **9.1.9 Women in construction**

Women continue to be underrepresented in the building professions. It is recommended that analyses are carried out and measures developed that are designed to make the construction professions more attractive to women.

#### **9.1.10 Shortage of skilled workers**

The shortage of skilled workers will not only affect the construction industry. In order to attract skilled workers into building a package of measures is required that address the image of the construction professions, provide concrete training and education, promote the mobility of workers and seek new workers internationally via a targeted campaign.

#### **9.1.11 Sociological studies**

Concrete, sociological studies into construction work and, in particular, the role of supervisors, forepersons and labourers are required in order to envisage and plan the future of these roles.

#### **9.1.12 Work, health and environment**

The relationship between new forms of work and their impact upon workers' health must be constantly investigated. Environmental changes also play a role in this relationship. The results of these investigations should lead to concrete measures in the areas of health policy and worker and environmental protection.

### **9.2. Corporate and project processes**

#### **9.2.1 Construction as a high-tech sector**

Construction is already a high-tech sector and this trend will intensify hugely in the future. This has hardly entered the general perception of the sector and intense PR measures are necessary in order to make use of this newly created image in order to recruit personnel.



### 9.2.2 Interdisciplinarity

Digitalisation affects all specialist areas and qualifications; hence, it can only be usefully addressed through interdisciplinary cooperation amongst, for example, experts in IT, construction practice, sociology, process management, machines and electronics, etc.

### 9.2.3 SMEs and decentralised economic forms

Targeted measures should be developed to support those companies that are responsible for the bulk of jobs in our economic region, e.g. a regional digitalisation campaign for SMEs, craftspeople and professionals. Digitalisation can even help to develop decentralised forms for workers and companies.

### 9.2.4 The affordability of digitalisation

Wherever companies appear unable to afford the investment costs of digitalisation (transformation costs) economic policy measures can be taken which also appear as socio-political measures in the sense of a WIN-WIN situation, because the loss of companies means the loss of jobs.

### 9.2.5 A workshop for the future of the social partnership

A workshop for the future can be established in partnership with companies of a range of sizes. The role of the workshop will be to constantly shed light on all aspects of digitalisation and automation in the building industry and develop consensual measures.

### 9.2.6 Industrialisation and the degree of prefabrication

The manufacturing industry has experience of digitalisation that the construction industry has yet to undergo. The sharing of this experience is vital, especially with regard to changing job profiles – such as the transformation of the construction worker into a factory worker or installer. This exchange of experience must, at least, cover the areas of labour law, working hours and remuneration.

### 9.2.7 New forms of labour and organisations

These are emerging but have yet to be comprehensively researched and tested. They are standard in the IT sector and becoming common in process management but they remain largely unknown in the construction industry. It is recommended these new, agile and team-oriented organisational forms are subject to pilot projects and trials.

### 9.2.8 Division in the construction industry

Trends suggest that we could experience a division in the industry that will not be in the interests of construction workers: between, on the one hand, highly-qualified and digitally supported skilled workers and, on the other hand, less qualified unskilled workers. If a division also develops between two sorts of companies that employ these two sorts of workers, the latter could find themselves in a socially precarious situation. Socio-political counter measures should be considered in advance.

### 9.2.9 Best practice and transformational processes

A positive culture of best practice examples and successful use cases can make a major contribution to launching the essential transformational processes and shaping these in such a way that they are acceptable to everyone. Theoretical studies can provide no more than a basis for these processes.

### 9.2.10 New types of jobs

Experience of other sectors tells us that digitalisation can also lead to completely new types of companies which can come into conflict with existing operations, e.g. Airbnb and UBER, etc. It is recommended that such innovations should be addressed positively and constructively and that efforts should focus on jointly agreeing socio-politically acceptable working conditions.

### 9.2.11 The use of a 'Baucard'

The Baucard is one of the most concrete applications of digital tools to affect construction workers. The related transparency has advantages and disadvantages. The system and conditions for using such a tool should be determined in such a way that the advantages take precedence.



## 9.3. ProCS – Procurement (tender & tender award), contract & settlement

### 9.3.1 Fair procurement

ProCS determines the quality of projects. Only fair procurement can lead to stable, sustainable development, reasonable profits for both sides, reasonable remuneration for workers and high-quality projects. These should be the concrete objectives of procurement policy and practice. Public sector projects are in a position to play a particularly pioneering role.

### 9.3.2 Lifecycle models

The traditional focus on designing and building is being replaced by a focus on building lifecycles and operation. This trend should be supported by public policy although there is currently a lack of a suitable procurement model with the corresponding long-term incentives. PPP-models basically meet these objectives but have other disadvantages. Forward-looking ProCS models should be developed, in both theory and practice. The long-term nature of such models should also bring positive effects for workers.

### 9.3.3 ProCS, successful projects and a positive image

ProCS has a significant impact on the success (or otherwise) of projects. Successful projects are amongst the key potential generators of a positive public image for the construction sector. ProCS brings together all the critical technical and economic processes that, at the end of the day, will also determine the long-term success of client and contracting organisations (companies) and, thus, of their employees. This is why it is recommended that maximum attention is paid to the issue of ProCS and that all the potential advantages of digitalisation in this area are carefully studied and applied.

## 9.4. Tools and the interoperability of software solutions

### 9.4.1 The protection of personal data and privacy

Digital tools and their practical application have a major impact on the protection of privacy – not least of the privacy of construction workers. This issue must be addressed critically during all future developments.

### 9.4.2 Security and the protection of health

Personal data are recorded. If used positively, these can play a key role in protecting the security and health of construction workers. The potential for misuse is to be prevented for all applications.

### 9.4.3 Flexibility and interoperability

For an SME-centric, regionally organised economy such as Austria and many European countries it is typical to place great emphasis on the avoidance of the emergence of uncontrollable monopolies and ensuring that a range of software solutions can be used in a flexible and interoperable way. This requires an appropriate market power structure that can be safeguarded by workers' representatives.

### 9.4.4 Digital infrastructure

Successful digitalisation in the countryside as well as in urban centres requires the appropriate infrastructure, including the provision of high-performance networks and adequate data transfer rates. It is the role of the statutory authorities to guarantee these.

## 9.5. Research and development

### 9.5.1 The need for research

Concrete, specific research into construction work must be initiated on the domestic, European and international levels with a deliberate combination of sociological and work and technology-related focuses. This should result in a concrete recognition of which professions will change and how in order to be able to use the research as the basis for concrete measures. Such research should be regularly updated (e.g. every three years) due to the rapid pace of development.

### 9.5.2 Research topics

The following topics for further research have emerged from this study:

- Detailed forms of development in the various construction sectors
- Investigations of regional characteristics – analysis and comparison, set in the global context
- Investigation of changes in corporate structures and the business models of both assembly and construction companies – including in the trans-regional context
- Investigation of the effects of the shift from construction to prefabrication and modular building
- Detailed investigation of the effects on the individual trades such as welders, assemblers, concrete workers, reinforcement fitters, masons and joiners etc.
- Studies of the shortage of skilled workers: trans-regional: which specialisations and where?
- Studies of the relationship between technology and user behaviour and the impact of this on quality – e.g. based on the example of BIM or the IoT & construction machinery
- ‘Disciplined Deployment’ – a study of reasonable forms of deployment and of the limits of ‘permanent availability’ at the interface between health, sociology, digital technology and building operations

Considerations of possible changes to the construction industry horizon and possible new types of projects lead to the following additional research topics:

- Questions related to increased energy demand
- Energy efficiency / green energy / sustainability
- The effects of climate change

### 9.5.3 Research practice

Research initiatives should be launched and placed by universities and other research institutions. Suitable research funding is available at the national, international and EU levels.

Long-term practical cooperation with the construction industry, construction companies, construction machinery companies and other suppliers and software firms, etc. is recommended.

Pilot projects should be implemented jointly with the above companies in order to test future developments at a small scale with low risk.

## 9.6. Education and training

### 9.6.1 Analysis of the current situation

Before concrete suggestions for the future can be developed, the current status of training and qualification measures should be surveyed in detail – particularly in the German-speaking and European Regions. Positive examples should be adopted and gaps in the range of training on offer should be filled.

### 9.6.2 Concrete training and qualification measures

Concrete suggestions for training and qualification measures for construction supervisors, forepersons and labourers should be developed. These programmes should be constantly adapted in line with ongoing technological developments and regularly tested to see where they remain relevant and where they should be updated.

### **9.6.3 An apprenticeship in “digital site know-how”**

An apprenticeship should be created focussed on digital skills in the construction process and on the construction site. It should teach a combination of IT and relevant specialist construction skills.

### **9.6.4 On-the-job training**

A working group should test concrete possibilities for the ‘on-the-job training’ of digital skills on the building site. A site-based training concept including certification should be developed together with representatives of both industry and academia.

### **9.6.5 Working with robots**

A working group should test concrete possibilities for a ‘Train / Lead-the Robot’ training programme together with representatives of both industry and academia, in order to establish the requirements for the new profession of ‘Robot Manager’.



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# National and International Impact of Digitalisation on Workers in Construction

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