150 YEARS

150 Years of PORR.

Building the Future.

powered by PORR

Foreword.

Ladies and Gentlemen,

Here at PORR, we hope to use this anniversary year to do much more than just look back on the last 150 years. A major milestone such as this is an exceptional achievement for any company; however, in reflecting on the past, we mustn't lose sight of the future. Our aim is to preserve what we have achieved to date, to pursue intelligent growth and to lay sound foundations for the next 150 years of PORR.

Building requirements have changed drastically in recent years – and will continue to do so. This transformation has significant implications for the construction industry as a whole. The future is digital. Paperless construction sites are now within reach. While construction will always require people, they will work with new tools and thereby gain time for use on new, more demanding tasks. Machines are becoming smarter: they will communicate with one another and perform standardised tasks independently.

For many years, PORR has been a pioneer of digitalisation in the construction sector. Through our application of building information modelling (BIM) and LEAN management, we're gradually developing the construction processes of tomorrow. We're investing in technologies and working to tailor them to the specific requirements of our employers. We're training our employees to ensure they're fully capable of working with these new tools and equipment. However, the best hardware and software is worthless without team spirit, transparency and a willingness from all project participants to engage in dialogue.

In this publication, a series of experts present and discuss the issues of the future. It shows what we're doing today and how we'll be working tomorrow.
I hope you enjoy reading it.

Best regards,
Karl-Heinz Strauss
CEO of PORR AG

PORR: A **pioneer** in the construction industry.

Innovative energy powering top performance – this has been the goal of PORR AG for the past 150 years. In this anniversary year, the company can look back on a unique success story: since its foundation in 1869, PORR has provided technical leadership in an array of demanding projects. In many European countries, PORR is one of the largest and leading providers of state-of-the-art infrastructure solutions. Today, PORR is a pioneer of digitalisation: possibly the most significant development for the construction industry to date, this technology is utterly transforming the sector.

150 years of PORR – 150 years of innovation.

Time and again over the last 150 years, PORR has delivered innovations and significantly shaped state-of-the-art techniques and technology in the construction sector. An early example of this is the conical concrete pile – a new method to create building foundations, designed and patented in 1911 by what was then Arthur Porr and Ottokar Stern's concrete construction company. Conical concrete piles fundamentally transformed construction methods and became one of the ambitious company's first trademarks.

In the aftermath of the First World War, Arthur Porr's legacy enabled the company to develop a new speciality: erecting suspension poles and anchoring towers in often inhospitable locations that were difficult to access. These so-called PORR masts continue to provide remote areas with electricity to this day.

From 1930 onwards, the company (then known as "Allgemeine Baugesellschaft – A. Porr Aktiengesellschaft") started work on one of the most extensive projects of the inter-war years: the Grossglockner High Alpine Road. It was a truly spectacular venture, during which the work in the largely undeveloped region was carried out at altitudes of up to 2,600 metres. It placed enormous demands on man and machine alike. In some places, material had to be dragged over the glacier on skids or transported in specially designed tray constructions. Some 150 workers' cabins wandered through the mountain landscape as work progressed. The project was completed successfully – and PORR had made an important contribution to improving mobility in Austria.

Energy for Austria.

From the 1950s to the 1990s, PORR played a leading role in another essential project for Austria. The goal was to use the Danube River – the country's main artery – to generate energy, thereby securing the national energy supply. In construction of the Ybbs-Persenbeug power station, PORR deployed a spectacular technique: weeks were spent paving the river bottom with planks of wood to make the construction pits water-tight. Only once that work was complete, could construction begin. PORR's representatives also put the company's inventive spirit into practice at the Wallsee-Mitterkirchen site. They exploited the route of the Danube to construct the power station in a dry construction pit beside the river on the inside of a bend. This new technique reduced the construction period for power stations from five years to three. Subsequent projects have even been completed in as little as 30 months.

Yet PORR's impact has not been limited to power station construction. From an early stage, the company gained expertise in just about every field of the building industry, including industrial and residential construction, mining, pipelines, tunnels, roads, underground car parks and railway lines. In this context, PORR developed the New Austrian Tunnelling Method, an innovation that revolutionised civil engineering around the world. The idea behind this involves exploiting the inherent load-bearing capacity of the mountains themselves. Furthermore, PORR played a leading role in the development of new road surfaces. In urban areas, PORR's ready-mixed concrete soon won out over all competitors.

It's perhaps not surprising, then, that PORR has repeatedly been awarded contracts for extremely complex projects. In the 1970s, 80s and 90s, the company played a decisive role in establishing Vienna's metro network – yet another construction scheme which required cutting-edge technologies, tremendous precision and the best engineers in the country.

Austrian roots – international markets.

PORR has applied its extensive expertise beyond Austria's borders for many years. It considers itself a European company with Austrian roots which – in special cases – also taps into attractive market opportunities outside of Europe. At present, PORR has operations in ten domestic and project markets and examines opportunities in other countries on an ongoing basis. In Qatar, for instance, PORR secured the largest order in its history in 2013, worth EUR 1.9 billion. Working together with local partners, the company constructed twin-bore tunnels to implement the Green Line, part of one of the world's most advanced metro networks, in the capital city Doha.

Another feature of the Doha project was the use of the internationally renowned Slab Track Austria track system – an elastically supported slab system PORR developed in conjunction with the Austrian Federal Railways (ÖBB). The Slab Track Austria system has been used as standard in domestic railway construction since the late 1990s. It has also been deployed in neighbouring Germany where, in addition to the Stuttgart 21 project, PORR is also involved in the country's longest railway project: the VDE 8 project between Halle and Coburg/Ebensfeld.

Digitalisation – a major technological breakthrough.

New digital technologies and innovations are transforming the world around us. Digitalisation is reshaping almost every aspect of how we live, interact and work together. The degree to which a company embraces these changes – and actively works to promote them – will be a decisive factor in its future success.

Digitalisation has long since begun transforming the construction sector. PORR recognised the early signs of this and has adopted a pioneering role in this crucial issue. By coming to grips with the digital transformation and the innovations it generates, PORR has already created tangible added value for clients and end users alike and continues to secure its sustainable competitive position. This in turn allows PORR to build on its unique technical excellence and innovative power.

Digital transformation:
The construction industry in flux.

In contrast to many other sectors, the construction industry has made little improvement in productivity in recent decades. However, increasing industrialisation and digitalisation offer entirely new opportunities. Initial estimates suggest it could be possible to increase productivity by 50-60% if construction companies grasp all the levers available. There is particular potential for improvement in design and engineering, supply chain management, employee qualification and, of course, new technologies – all fields in which PORR is already particularly well positioned. But the underlying conditions must be right for seizing this potential: this requires a functioning "ecosystem" within the industry as well as a sensible regulation in order, for instance, to set common standards.

The enormous potential is derived from the ability of digitalisation to transform the entire value-creation chain in the construction sector: from the original concept on to planning, cost estimation and execution and all the way through to commissioning and maintenance. In some cases, it gives rise to entirely novel approaches:

- **Integrated planning.** Integrated planning makes it possible to optimise the construction process in its entirety – including work with subcontractors.
- **Modularisation and standardisation.** Increased modularisation and standardisation enable us to prefabricate more components before they reach the construction site – which cuts costs by almost one-third while reducing construction periods by almost half.
- **Automation.** Automated processes and integrated control of machines and resources makes the entire construction process markedly more efficient.
- **Digital twins.** Creating digital twins of structures makes it possible to keep one eye on a building's future usage even during the design and planning stage and thereby optimise its energy efficiency or maintenance requirements. What's more, the digital twin can be used to track construction progress and compare it with designs in real time. Gathering all data in one central location enables design, execution and construction monitoring work to be coordinated more effectively.
- **Artificial intelligence.** Artificial intelligence and advanced analytics allow us to process volumes of data on an unprecedented scale. This opens up new opportunities for project optimisation: for instance, an artificial intelligence (AI) can identify an error or defect, even before it occurs. This advance also enables us to achieve optimisations across numerous projects – for example by algorithms that can analyse completed projects to identify success factors for future use.

Digitalisation is bringing immense potential – not only for the construction industry itself, but also for clients, end users, local authorities and those working in the sector. Ultimately, everyone stands to benefit from digitalisation.

- **Shorter construction periods.** As construction schemes can be completed considerably faster, clients and construction firms can react more flexibly to changing demands and are better able, for example, to combat housing shortages. In addition, more infrastructure projects can be completed within the original timeframe and budget. It also reduces construction firms' financial expenditures.
- **Lower costs.** First and foremost, accelerated execution cuts the overall costs for clients and end users. In the conventional construction method, this is the stage that incurs the most costs due to the highly labour-intensive nature of construction site work.
- **Higher quality.** If more components are prefabricated and only need to be installed on site, this reduces errors (e.g. mismatched dimensions) and therefore also the reworking required. If creating and processing manual error logs can be avoided, then conducting quality checks on acceptance of the completed project will be easier.
- **Less risk.** As forecasts of key parameters – such as project duration and costs – become more accurate, and construction progress and material availability can be monitored in real time, the risks in a project can be markedly reduced. Construction firms have less need to set aside provisions, there are fewer legal disputes and potential amounts in dispute are reduced.
- **High-quality employment.** Digitalisation is relieving people in the construction industry of repetitive and physically strenuous tasks. This affords them valuable time for more worthwhile tasks (e.g. technical innovations), making jobs in the sector more attractive.

Individual companies in the construction industry have made significantly varied progress in seizing the potential of digitalisation. PORR, however, is determined to make full use of the opportunities in this shifting competitive environment and thereby strengthen its position as a pioneer of digitalisation in the European construction industry.

PORR goes digital: **Added value** for companies and clients.

In recent years, PORR has promoted significant digitalisation initiatives and invested considerable sums in upgrading its IT infrastructure. The company aims at tailoring its use of innovative technologies to optimise the entire value-creation chain: from contract acquisition on to planning, cost estimation and execution of a project and through to commissioning and ongoing maintenance. Here, PORR has structured all its initiatives in ways that deliver significant benefits, not only for the company itself, but also for its clients and the end users of its constructions. PORR is also engaged in various bodies in order to develop mandatory standards of digitalisation for the entire sector.

What is BIM?
To put it simply, building information modelling (BIM) is a digital approach to project implementation in which the structure is depicted as a computer model. BIM makes it possible to portray relevant aspects of a project, such as dimensions, material properties, costs and time, in a single model. A further benefit of this approach is that all parties involved in the project – from the employer through to subcontractors – work together on the same model. This means that plan dimensions are never considered in isolation but are viewed within the overall context throughout the project lifecycle.

Acquisition: The client's partner from the outset.

Acquiring clients and winning contracts depends on seeing things from the client's perspective and developing the right solution for them. With the help of BIM, PORR can present several virtual models of planned constructions to a client before the contract is even awarded. Each model also makes it possible to simulate the expected overall construction period and how the overall costs differ between variants. The use of virtual reality (VR) and augmented reality (AR) is a particularly effective tool in helping clients to gain a better visual impression of the project. Virtual tours of models make it possible to examine technical details and design parameters ahead of time, and optimise them where necessary. As well as simulating day and night, the BIM model can also depict parameters like light incidence or temperatures in different seasons (Figure 1).

The benefits for clients are clear: they can decide where to award the contract based on a broader pool of data. By doing this, PORR is embracing the opportunity to demonstrate its technical expertise and position itself as the best partner for project planning and execution.

Fig. 1: Construction process simulation in BIM

IN PRACTICE ***An example of BIM:*** *As it happens, the ability to run through different scenarios with a client has proven to be a significant competitive advantage in winning contracts. With this method, PORR was able to win the contract to conduct planning work for the new BMW office building in Munich's Freimann district, beating off stiff competition in the process (Figure 2). During the acquisition phase, the challenge was to assess the building's planned superstructure for potential optimisations. PORR took an early preliminary design, examined it and refined it before developing six design variants. These formed the basis for further dialogue and planning with BMW. Thanks to the virtual model, all stakeholders in the project were shown a vivid depiction of the execution of the structural work. Following subsequent examination of the variants' cost efficiency, the BMW team was able to select the best option.*

Fig. 2: BMW Freimann project

Planning and cost estimation: Higher quality, faster processes.

The use of digital technologies like BIM has markedly improved performance in the planning stage. Because all parties involved in a project work to the same standard and on the same model, planning is more transparent and precise, which significantly reduces a project's duration. This makes it possible to avoid errors due, for instance, to there being too many interfaces and media used – such as when incorporating amendments. On the key benchmark value of the number of promises kept, a value which measures how many activities planned for a week are actually carried out, PORR achieves a figure between 80 and 100% in some cases, much to our clients' satisfaction. The industry average for this parameter is 54%. Digitalisation has also significantly enhanced the productivity of cost estimations. Indeed, PORR can now make cost estimations for 30% more projects in the same time and with the same resources as before.

LEAN design: Alternative design options to optimise costs.

Changes during the planning stage are not only time-critical but also tend to be cost-intensive. PORR can use BIM models to generate cost-effective iterations of different design options. This enables us to examine how materials and production procedures might be optimised to reach the budget targets specified by the client.

IN PRACTICE *After planning work for its new office building in Freimann, Munich, had been completed, BMW was forced to make wide-reaching changes, due to the introduction of new standards for all BMW offices around the world. Thanks to BIM, it took PORR just five hours to calculate the implications of the required changes for the construction period and costs. PORR then needed only three weeks – rather than the standard six – to implement these changes, thanks to its application of LEAN design principles. Consequently, the duration of the execution stage and the building's overall costs were not unduly affected.*

In the planning stage of the BMW Freimann project, the PORR team took the time to structure various sub-processes, such as approving technical details, more efficiently. The conventional approach would have involved numerous stages carried out manually. However, following interdisciplinary process analysis, PORR was able to streamline its activities from 14 separate stages to just five. For the client, this meant a considerably simpler process.

In a further benefit of the LEAN design approach, when planning the BMW building's superstructure, the BIM model identified at the very outset several areas that were critical from a structural perspective. Using a "traffic-light" system (of red, amber and green colour coding), relevant parts of the structure were prioritised and the results passed on to other specialist units working on the project. This enabled the M&E planning unit to determine the location of conduits and cable trays early in the construction process. The benefit: fewer amendments and reworking required as the project progressed.

The BIM library: Standardising construction elements for more efficient planning.

For many years, standardisation was an alien concept in the construction industry. To put it bluntly, new "prototypes" were pumped out time and time again. This approach would have been considered utterly absurd in the automotive industry, for instance. No customer would buy a prototype car that was expensive, untested, prone to defects and without any spare parts.

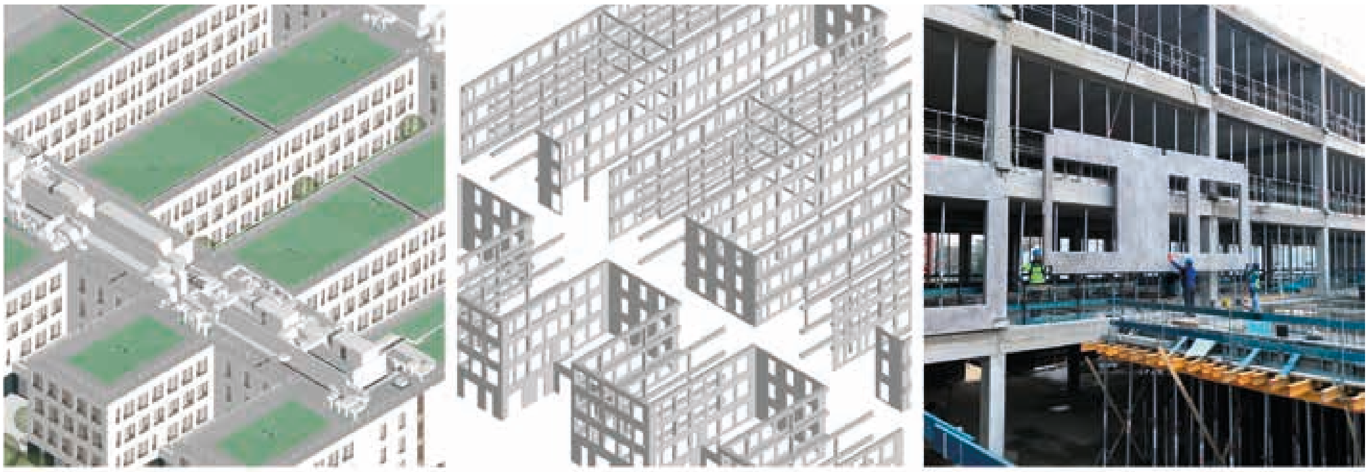
Over time, components have become increasingly standardised, including in construction. As a pioneer in this field, PORR has developed a comprehensive library of BIM data. It comprises digital records of all common construction elements. In new projects, planners and designers can draw on this pool of optimised, universally applicable components. Inputting parameters such as the material, dimensions and installation site instantly produces a complete, three-dimensional construction component – including estimated cost and delivery time. This generates options for building plans which, while flexible, still fit the plans precisely and provide clearly stated costs. The added precision reduces the risk of costly deviations at a later point. Clients also benefit from this accelerated planning and improved forecasting, because the final costs and the commissioning date for the building can be estimated far more accurately.

There is another positive effect: the clearly structured BIM library makes inducting new employees faster and more straightforward. The library is easy to use and the help tools, such as a wiki page with tutorial videos and sample projects, make it easier to get started.

IN PRACTICE *In the BMW Freimann project, all structural slabs, columns and foundations were constructed using standardised libraries. Only the beams required project-specific adjustments in some places due to the complexity of semi-finished components. Ultimately, about 80% of the structural work used standardised parts (Figure 3). The same was true of the interior, where all walls were erected using a standardised library.*

Importing relevant information from subcontractors into the BIM model and defining interfaces is a key challenge. If PORR is not involved in a project's planning stage, the execution stage requires data to be coordinated with all other technical crews working

Fig. 3: Prefabricated construction based on a BIM model



BIM model as a starting point | **Model-based data on prefabricated parts** | **Prefabricated parts are moved into place**

on the structure. At present, this usually relies on extrapolations and matrices. This is why defining uniform standards is so important: it simplifies the exchange of relevant BIM data throughout the value-creation chain.

Virtual & augmented reality:
Early identification of quality issues.

With the help of augmented reality applications, site managers can now use their smartphone or tablet to superimpose BIM model data onto the actual building. Even when construction is just beginning or during the shell construction phase, this shows how the building will look in a few weeks' time. If they identify the need for any changes, the site managers can send screenshots with comments directly to the planning unit from the construction site.

So now PORR can plan the construction process even more precisely. Quality checks on the construction site are becoming simpler and require fewer personnel. Thanks to visual error detection, potential quality issues can be identified and resolved earlier than before.

IN PRACTICE *In the BMW Freimann project, pipes were identified that, according to the planning model, were to extend through a wall without an opening. This error could be remedied before the execution stage (Figure 3).*

Execution: Faster, more cost-efficient processes.

Especially in the execution stage, new technologies are set to deliver considerable savings, since this phase is typically where the bulk of the project's costs are incurred. Optimising the construction progress for all parties involved in a project also significantly shortens the construction period. For instance, new rental apartments can be completed in just nine months instead of the previous period of two years. Two examples of new approaches in the execution stage are LEAN construction and asset tracking.

LEAN construction – streamlined, transparent processes.
In execution, PORR uses LEAN construction – the consistent avoidance of inefficiencies. These include, for example, standby times between different technical crews, reworking, surplus production or long transport routes. PORR is one of the LEAN pioneers in the construction sector and offers training in LEAN for both employers and subcontractors.

LEAN methodologies are used above all for schedule planning, with the fundamental idea being to divide the construction site into sections with comparable amounts of work. Each of these sections is then completed according to a clearly defined plan that integrates all the technical crews. The BIM model makes individual work packages and their dependencies transparent.

By adopting the LEAN approach, PORR is better able to monitor the project's progress – including among subcontractors – and intervene faster if defects arise or resources are lacking. This is not to forget how the approach accelerates project implementation, as the efficient planning removes the need for time buffers in scheduling. Meanwhile, the client also maintains an overview of the project's status at all times.

PORR has developed a standardised procedure for using LEAN methodology to set up a construction site (Figure 4). The most important success factors are the interdisciplinary exchange and regular communication between all parties involved in the project.

Fig. 4: PORR's LEAN approach

LEAN acquisition

- Project analysis
- Milestone plan
- Potential analysis
- Cost determination

LEAN training & qualification

- Principles
- Methods
- Simulations
- Training for all internal and external process owners

LEAN implementation

- Overall process analysis
- Milestone plan
- Schedule planning
- "Big room" installation
- Coaching for specific units, technical crews, specialists

LEAN project management

- Weekly PEP(4) meetings
- Daily stand-up meetings
- Moderation from LEAN manager

One challenge for the stage-scheduling process is integrating the planning and execution processes; it requires continuous comparison of planning data on the basis of weekly adjustments to execution planning on the construction site.

IN PRACTICE *The recent project in Freimann, Munich, illustrates the extent to which the LEAN approach can help to accelerate progress: PORR was able to reduce the originally proposed construction period of 20 months to just 16 months. Even our employer, BMW, was surprised. Due to concerns that the new schedule was overambitious, when ordering the office furnishings, the delivery dates were arranged based on the original schedule. In actual fact, PORR managed to shave off a further two weeks with a quick redesign of the garage entrance.*

Another key element of LEAN methodology is the systematic standardisation of construction elements. In collaboration with its subsidiaries, PORR has developed standardised pipe elements for office buildings. Pipes therefore no longer need to be manufactured individually. By purchasing components in larger volumes, this method also saves on costs. Installing these standardised elements is also simpler as they cause fewer on-site mix-ups and queries.

IN PRACTICE *In Freimann, the construction process was optimised so that the manufacturer could already assemble individual pipe elements. This saved a great deal of time on site and eliminated a potential source of errors.*

Construction elements are now delivered on palettes using just-in-time systems and in the precise order required for installation. For example, all building services are installed on a single scaffold – heating, cooling, ventilation and sanitary systems are installed by crane as a block system. Effective communication with construction planning and scheduling units is decisive: with the LEAN planning approach, the installation of these elements must be precisely coordinated with the other technical crews.

Asset tracking: Optimised use of equipment and 100% recovery rate in case of theft.
PORR Equipment Services (PES), a subsidiary of PORR AG, also relies on digitalisation to achieve significant productivity gains. Since 2016, PES has installed telematics systems in its construction machinery and vehicles in order to record and transmit their operating hours and kilometres travelled in real time. The system is easy to operate – employees only need a short training session on site.

This networking offers numerous benefits, not least the ability to deploy vehicles and machines more effectively. The utilisation data is forwarded to the site managers so that they can analyse which equipment is used less often while still incurring internal rental costs. The crucial asset-turnover ratio – which compares net sales to the average total value of the equipment fleet – improved markedly from 2014 to 2017, rising from 13.2% to 14.2%.

On the other hand, monitoring the operating hours of specific equipment also makes it possible to plan maintenance intervals more efficiently. Improving the availability of machinery results in fewer unwanted work interruptions on the construction site.

Furthermore, asset tracking supports decisions on whether or not equipment is worth repairing. A mechanic can use an app that was developed in-house, to determine the revenue generated by the machine to date, the costs it has accumulated in repairs so far and the amount remaining for work on the machine before repairs are no longer cost-effective. The app provides a corresponding colour-coded recommendation. As a result, the ratio of repair costs to the average total value of existing assets fell from 3.3% to 2.2% between 2013 and 2017.

Asset tracking also plays an important role in procurement. PORR is able to make more informed procurement decisions based on millions of data points on historic vehicle and machine performance. What's more, using a GPS-tracking tool also makes it much easier to recover stolen vehicles and machinery – the company's recovery rate has now reached 100%. This corresponds to an annual saving of EUR 0.5m.

Facility management: Cost reductions for clients.

Once a project has been completed, the BIM model can be used to facilitate the building's ongoing operation, such as in facility management. This is particularly beneficial for clients: they gain structured and comprehensive documentation about the building that provides a transparent view of the networks, connections and dependencies between various components of the building services. This makes commissioning easier while also reducing maintenance and operating costs that make up about 80% of the total costs of an asset over its entire lifecycle. For instance, maintenance intervals can be more accurately predicted. Moreover, the client can use the performance data on individual components when making subsequent purchase decisions.

IN PRACTICE *Once the Freimann project had been completed, PORR handed the entire BIM model over to the BMW facility management team. They were then able to use the model to discern key parameters for maintenance and consequently optimise the entire building's maintenance plans for the coming years. The model serves as a basis upon which to produce more accurate forecasts regarding components' lifespans and when they will require maintenance or replacement. In addition, the entire BMW maintenance team can access the model in order to be better prepared for upcoming maintenance work. Already during the planning stage, PORR and BMW held several meetings to establish what information was relevant for facility management and should therefore be incorporated in the BIM model.*

Overarching approaches: Moving towards the paperless construction site.

The construction site of the future is paperless. Digital technologies are making it possible to automate processes consistently throughout the entire value-creation chain. PES has already taken its first steps towards this objective. Introducing more efficient processes has not led to any layoffs or job losses. Instead, PES can now process greater volumes with a stable workforce occupying higher quality jobs.

One example of paperless working is digital dispatch notes, which make it possible to register the transfer of a vehicle to a building site using a tablet or smartphone. It provides the user with an overview of all key information about the vehicle. Maintenance operations have also moved away from burdensome bureaucracy. In the past, when the system received a maintenance notification, the order arrived at the workshop from the printer. The engineer had to check the boxes for all completed work and enter the time spent doing so. The foreman then needed to sign it off before the accounting staff entered the details into the accounting system – all done exclusively by hand.

A new app makes this process noticeably easier: it displays the required tasks to the workshop engineer – for example, it might indicate that a machine needs a hydraulic oil change. When the engineer finishes the task, the software automatically posts the time taken on the job. The workshop foremen can then view the entry directly in SAP. The app also displays what materials, such as oils or greases or spare parts have been used and posted to the workshop order. PES believes that, by early 2019, the majority of order papers will be handled using the app – making a significant contribution to the environment and sustainability. Just by digitalising maintenance orders, PES is set to save 170,000 sheets of paper per year (Figure 5).

Fig. 5: 170,000 sheets of paper saved

The time savings are similarly striking: digitalising the dispatch notes for machinery and vehicles will save around 6,000 working hours per year, with up to 55,000 hours saved on acknowledgements. The average time for acknowledgements fell from an average of 22 minutes to an impressive two minutes. The process of completing a dispatch note now takes just four minutes, down from ten. Employees can use the time saved for more creative activities.

Digital measures provide savings.

- Construction time reduced by up to 50% thanks to LEAN methodology and BIM
- More than 1.5 million m^2 area planned digitally
- 100% recovery rate after theft, thanks to GPS tracking
- Machinery repair work down 30% thanks to new app
- 170,000 sheets of paper saved per year in equipment management alone, thanks to digitalisation of maintenance orders

Training and development: People are the key.

The rise of PORR over the past 150 years would not have been possible without the dedication and expertise of its employees. The pioneering spirit and passion demonstrated by all PORRians will remain decisive factors for the company's future success.

Digital information and processes will increasingly shape the working world of tomorrow. As conventional jobs and roles change, new requirement profiles continue to emerge. Digitalisation is increasing the value of many jobs: it often takes monotonous or physically demanding activities out of human hands, freeing our employees up for more challenging tasks. The use of modern technology in the construction industry is making many positions even more attractive.

By the same token, key employee qualifications and skills are also changing. For instance, staff need to be able to handle network data with confidence and work well in a team. For this reason, when applying LEAN methodology or developing innovations, PORR consciously endeavours to integrate all employees as soon as they are hired and facilitates close collaboration across departmental boundaries.

For PORR, one thing is clear: staff training and development has acquired decisive importance in this age of digitalisation. Accordingly, the company continues to aspire to be a leading company within the European construction industry in employee training and development. The PORR Training Campus, for example, is open not only to apprentices but also to all of the company's industrial workers. A key focus of the training program is the digIT LearningMap, a resource that teaches key digital competencies. In the PORR Academy, employees have access to a variety of e-learning resources to develop specialist skills and build their profile.

The introduction of new processes like LEAN methodologies is always accompanied by intensive employee training (Figure 6). This training always features strong practical relevance, as training is often given on the job. The aim is to provide employees with practically relevant training rather than overwhelming them with technical minutiae. Experience has shown that deactivating old processes as soon as new methods are implemented is effective because it forces employees to come to grips with the changed circumstances. The more experienced employees function as coaches and, in this way, colleagues support one another and lend each other a helping hand.

To make the employee onboarding process simpler, PORR develops internal wikis with tutorial videos and sample projects – such as for BIM. This accelerates the initial adoption period. In cost estimation, for example, new team members can start making active contributions to estimation models after just a few days.

Another important aspect is helping employees to maintain a healthy work-life-balance. PORR has developed a diverse range of measures in this area, ranging from home-office working to a company health drive, and even parent-child offices as a stopgap measure when childcare falls through. Such initiatives not only benefit the workforce but also the company as a whole, as they help PORR to position itself as an attractive employer in the competition to attract talented young specialists. Recruiting and motivating young talent – a particularly scarce resource in the construction industry – at an early stage is absolutely vital.

Fig. 6: LEAN simulation

Looking to the future:
Continuing our success.

The digital transformation in the construction industry is far from over. The coming years will not only see sustained change in what we build, but also in how we build and the business models we use to do so. PORR is ready to face the challenges of tomorrow.

What we build: Intelligent infrastructure and buildings – networked systems and global products.

The future belongs to smart cities and smart infrastructure. Buildings, roads, vehicles, power stations, and more besides, are turning into sensor and data platforms, interconnected in vast, highly complex networks (Figure 7). Cities and regions will compete to provide citizens with an attractive, liveable environment while offering companies effective infrastructure to help them compete in global markets. By working in conjunction with their partners, construction firms will integrate new technologies in their buildings; modern construction materials and technologies will allow them to create new forms of design. Pioneering, planning and production processes will minimise the noise pollution, dust exposure and traffic burden caused by construction sites, while artificial intelligence will enable firms to construct infrastructure and buildings that adapt flexibly to their users' requirements.

Infrastructure technology: Smart cities and electrifying road networks.

Cities are currently subject to unprecedented pressures: as their populations grow, infrastructure systems are increasingly overstretched. Until recently, intelligent technologies were primarily seen as tools for making cities more efficient. Sensor data and high-tech command centres offered entirely new opportunities to manage complex processes and automate infrastructure systems. In future, however, these technologies will become even more important and thereby exert greater influence on the lives of citizens, and become even more society-oriented as they develop.

Today's smartphones are becoming access portals: they provide traffic information and health data in real time; they display security warnings and disseminate news to local communities. Real-time data makes it possible to monitor events as they develop, in order to better understand changing patterns of demand and react more quickly and cost-effectively. Let's consider two examples. In London, the Citymapper app provides users with real-time information on traffic jams, road closures and departure times for public transport, as well as the ability to compare different routes to opt for the most efficient mode of transport. Secondly, Singapore has installed movement sensors in state-owned residential complexes in order to notify the relatives of elderly people if their movement patterns change unexpectedly – which could be a sign of health problems.

Smart city applications have the potential to make cities both more liveable for their residents and more productive locations for companies. Based on initial experience, these applications can, for example, cut road traffic deaths by 8-10%, shorten the response times of emergency services by 20-35%, speed up the average commute by 15-20%, bring down sick leave by 8-15% and reduce greenhouse gas emissions by 10-15%.

Smart cities present the construction sector with novel challenges – such as the replacement of concrete which, while universally applicable, is hardly eco-friendly and a relatively inflexible construction material over a structure's lifecycle. At the same time, however, they offer substantial market opportunities. Approximately 60% of the initial

Fig. 7: Smart cities

investment needed to implement the entire range of applications for intelligent systems to create these smart cities could come from private enterprises. Customer requirements will force actors in the construction industry to re-evaluate their products and services in order to fulfil raised expectations in terms of quality, cost and efficiency.

A further challenge lies in improving the efficiency of existing infrastructure. Although the importance of reducing the use of fossil fuels to protect the environment is clear, the volume of road traffic continues to rise significantly. Various solutions can be combined to reduce CO_2 emissions: in addition to switching to biofuels and reducing energy use, electrifying road networks is also an approach well worth pursuing.

If, for instance, trucks were to travel on electrified roads, energy consumption would fall markedly. Converting road traffic to run on electricity reduces carbon emissions by 80-90%. This transition would therefore not only protect the climate but would also be a cost-effective one that combines the benefits of rail with the flexibility of the road when transporting cargo. Sweden's eRoadArlanda project is one example: electric vehicles can charge their batteries as they drive on the country's first electrified road. The underlying idea is to extend the limited range of electric vehicles so they can run on batteries on minor roads and then recharge their batteries on electrified main roads. Electrical systems would be far superior to vehicles with combustion engines, especially for very long distances. If the new system were introduced in Europe, it would be possible to drive from the northern tip of Norway to Malaga in southern Spain without stopping to refuel. Such a solution, which would require changes in transport and environmental policy, would also be attractive for the construction industry and have immense market potential.

Building technology: Networking through the IoT.
Networking systems within buildings goes hand-in-hand with work to develop new products and services. In order to create specific applications, correlations need to be identified between the numerous building sensors that generate millions of data points and external data points, such as weather data. While traditional data models use historic data and expert assessments to attempt to identify relationships between independent variables, this process will be automated in future by using machine learning to search for variables that enable the most accurate forecasting possible. The potential uses are countless, ranging from intelligent lift controls, which communicate and coordinate via IoT (Internet of Things) platforms, to better forecasting of maintenance cycles and significant savings through optimised energy management.

Some companies, such as Schneider Electric and Siemens, have already begun to integrate hardware and software components with building automation systems, thereby creating control networks in which data can be collected, analysed and harnessed. This is indicative of a clear trend in which companies are moving away from asset-based business models in favour of services. In the construction industry, this trend also offers opportunities to collaborate with partners to integrate the requisite technology in buildings and thereby create new service packages, for example in energy management.

Efficiency in the desert
Becoming one of the most efficient and sustainable hotels of the Hilton brand is certainly a bold aim. Nevertheless, thanks to Schneider Electric's EcoStruxure Building platform, the Hilton Garden Inn Dubai Mall of the Emirates managed to improve its energy efficiency by 44% without compromising guest comfort.

(Source: Schneider Electric website)

How we build: New technologies and combinations – towards promising application clusters in the value-creation chain.

New technologies are not only changing what is built, but also how structures are built. Global investment in new technologies has doubled in the sector over the past ten years: from 2008 to 2012, construction firms invested about USD 9 billion in this way, and about USD 18 billion from 2013 to 2018 – with this trend set to continue. While the array of digital solutions becomes ever more diverse, certain application clusters are forming (Figure 9).

Digital twins.
In future, the importance of digital twins is set to increase further. Overlapping photos and (if necessary) supplementary laser scans, mainly drone-shot images and floor pictures, are processed to generate spatially classified illustrations of structures with the desired degree of accuracy.

By modelling buildings to create a digital twin before construction begins, planners can simulate system operation in the future long before the first excavators roll onto the construction site. This means, for instance, that evacuation procedures can be simulated in order to find the optimal layout for emergency escape routes. The building systems' performance can also be optimised ahead of time by using the digital twin to test and enhance heating, ventilation and air-conditioning systems under real operating conditions. Conducting real-time comparisons between construction progress and design blueprints also reduces the need for reworking. Planning, execution and monitoring tasks can be coordinated more efficiently because all the teams have access to the same centralised pool of data. This will soon make it possible to dramatically shorten on-site decision-making cycles – in some cases from months to days. Once constructed, a building's actual characteristics can be fed back into its digital twin. On a smaller scale, photo data is reverse-calculated to generate the building's geometry in order to create "as-built" models that depict the scanned geometry of the completed construction scheme.

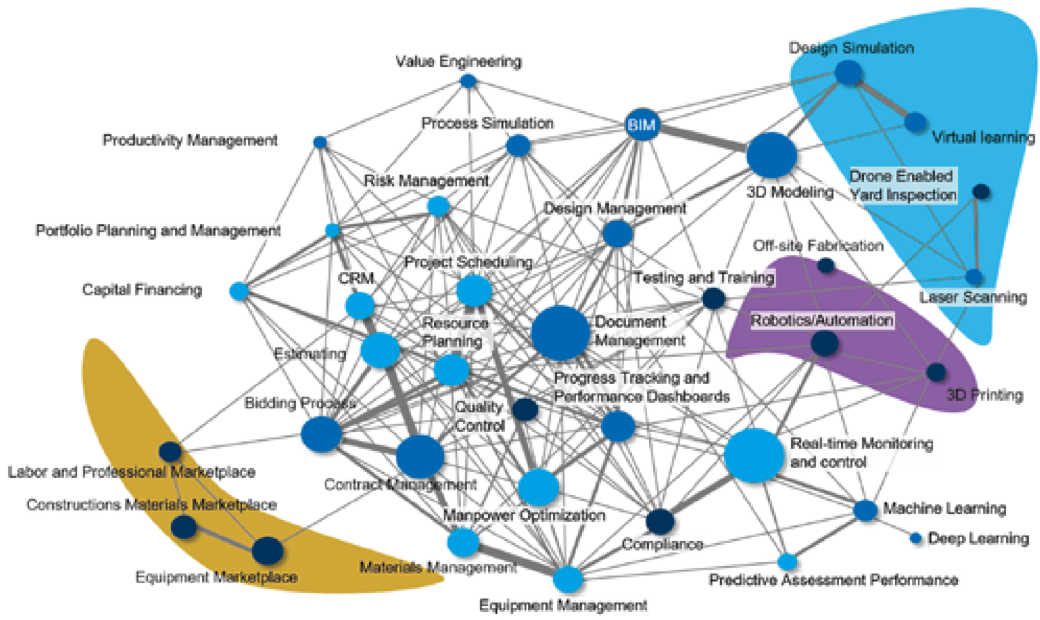
3D printing/modularisation/robotics.
Standardisation will continue to accelerate, culminating in the industrial mass production of components before they reach the construction site. This could lead to construction cost savings of up to 20%. Examples of applications include fully automated production processes that translate 2D drawings or 3D models into prefabricated construction components, or production directly on the basis of 3D models. Construction-related robotics – such as welding robots – and 3D printing of components, which otherwise have long lead times, can deliver improved cost efficiency and enhanced quality.

The first 3D-printed steel bridges are already on the market (Figure 8). Take MX3D, for instance – a company that produced a fully functional 3D-printed bridge made from premium steel to span a canal in Amsterdam. To achieve this, they fitted industrial robots with specially developed tools and controlled them with specially designed software. The material usage was 30% lower than usual. Other benefits include fewer human errors and more flexible schedules, as the machines can work continuously without losing time or concern that their attention to detail might flag.

Fig. 8: 3D printing in construction

Artificial intelligence/analytics.
In future, machine learning will appear throughout the entire value-creation chain, in particular to track progress – that is to say, to compare actual construction site progress with plans and schedules. As a result, it will be possible to identify and remedy deviations from the planned construction period at

Fig. 9: Application clusters in the construction sector



an even earlier stage. One example of how advanced analytics could be applied to infrastructure projects across the board can be found in the Crossrail project of London's underground rail system. The project networks 250,000 sensors throughout the city in order to understand the spatial and temporal relationships that connect them – and thereby identify ground movement patterns. Analysing this data and constantly working to enhance data monitoring makes it possible to forecast short-term and long-term soil displacements and issue warnings of major displacement incidents ahead of time. Thanks to automated anomaly detection, field engineers can be informed of such hazards more quickly, thereby significantly improving risk management. What's more, this process reduces measurement and monitoring costs by over 20%. That, however, is just the beginning: in future, sensors on buildings and other data points will be combined with machine learning in order to conduct automated analysis and prioritisation of all factors, thereby improving project performance. This will, in turn, enable actors to take the best possible decisions to ensure a project's success – such as what materials to use, which teams should collaborate and in what combination, how financing should be structured, and how best to organise construction site logistics.

Supply chain optimisation/marketplaces.
At present, procuring building materials, equipment and services remains a largely manual process. However, start-ups and suppliers have now begun to create digital marketplaces that bring supply and demand together. This development has the potential to revolutionise the supply chain: these marketplaces provide pricing transparency and streamline the procurement process. Some manufacturers, for instance, offer a 5D BIM visualisation combined with a digital ordering process, demand-based production and just-in-time logistics. This enables stakeholders to oversee and manage the entire work process – from planning and design through to approval and acceptance – from a single source of information.

Emerging business models: New market rules – culminating in vertical and horizontal integration.

The roles of employers, main contractors, subcontractors and suppliers are being transformed. Collaboration between individual actors will become more important, not least in making data usable in a shared ecosystem. At the same time, disruption should be expected throughout the sector, potentially due to market competitors from outside the sector. Major US tech companies have already announced their intention to serve segments of the traditional construction industry; take Google and its Sidewalk Labs project, for instance. Other companies, such as Katerra, have already embarked on comprehensive vertical integration. By bringing architects together under one roof with the companies that realise their designs to establish a one-stop service for construction projects, they aim to offer a globally standardised approach to process future projects.

Participants at the Global Infrastructure Initiative summit in 2018 agreed that business models could yet move in different directions. A transition towards vertical integration is possible, especially in light of the trend of modularisation. At present, subcontractors and main contractors act like OEMs (original equipment manufacturers) for prefabricated solutions, or at least undertake key elements of the value-creation chain in order to come closer to clients. Companies like PORR, which use sensors during the construction phase to gather important information for subsequent operation, could thereby provide services to end clients and undertake asset operation, for example by managing energy. Construction operations would therefore move away from pure execution and develop into service packages. New forms of horizontal competition will also arise, such as when individual companies merge to establish a consolidated platform. This could serve both to defend against new competitors – by forming procurement platforms to ward off US companies such as Amazon – and also to develop new services, such as optimising construction machinery to serve other companies executing projects.

The future has already begun:
A glimpse of the year 2030.

PORR is digitally implementing infrastructure and residential construction projects from start to finish and offering clients an extensive range of services. As early as the planning stage, a digital model in the form of a hologram allows the client to envisage and design their future surroundings in full size; the design incorporates usage and operation insights gleaned from millions of similar structures around the world. Simulating construction processes and building operation using different usage variants facilitates straightforward construction and reliable, efficient operation. Then, based on the model, suppliers and subcontractors are automatically commissioned to produce and supply the required components; this includes a precise delivery date, location and price. Specific components like walls, stairs and technical installations are individually produced based on the digital model before being pre-assembled and delivered on schedule to the construction site for installation.

All parties involved in the project work simultaneously on the same data; any modifications made necessary by client requests, technical changes, supply chain issues or external factors such as severe weather, are directly integrated in new schedules and communicated to all project participants. Upon delivery to the construction site, components are rapidly installed without errors and with the utmost safety for site workers. Drones or augmented reality solutions automatically monitor construction progress and quality; the digital twin is updated to reflect the actual state of construction.

The project is completed and handed over to the client on schedule, at which point the operating parameters throughout the building have already been tailored to the usage requirements. The user receives operating instructions and maintenance plans – including schedules, costs and contacts – sent straight to their computer or smartphone.

PORR employees and partners enjoy state-of-the-art workplaces in a profitable, innovative environment. They feel certain they are part of an attractive, competitive company that is working in the interests of both its clients and society as a whole.

Guest article.

The construction industry was once considered the benchmark of a society's technological development. Structural masterpieces and major projects garnered global recognition for cities and regions around the world. In recent decades, however, the construction sector has ceded its position as a leader of technology. As an industry, it has made less progress in productivity than almost any other sector. Nevertheless, by contributing 13% of global added value and with an annual market value of around 10 quadrillion US dollars, construction remains the world's largest industrial sector – and, thanks to high infrastructure requirements, continues to grow at a rate of over 3% per year.

In recent years, average investment by the construction sector in research and development as well as IT has amounted to approximately 1% of turnover, compared to 2-6% in other industries. This complicates the sector's starting position: progress and change have reached it far later than other industries. In addition, many countries are in the grip of a glaring shortage of specialist construction workers, leading to significant delays of major projects. In Germany, for example, if current productivity levels are maintained, the construction sector will require 130,000 additional workers to handle the forecasted increases in construction volume.

However, digitalisation, industrialisation and globalisation have now reached the construction sector: their influence will rapidly and fundamentally transform the sector's structures and procedures. In the last five years, global investment and financial transactions in construction technology firms and start-ups have doubled, rising from USD 9 billion to USD 18 billion. A survey of participants at an international construction engineering conference showed that around 60% already had experience with 3D BIM systems, with 20% having worked on 4D or 5D models. In public calls for tenders, the use of BIM technology is increasingly specified as an essential requirement. Modular, prefabricated construction methods are becoming ever more prevalent. In Scandinavia, 45% of all residential buildings are now erected using prefabricated components; in the hotel sector, the proportion of modular, prefabricated rooms in the England and North America is rising quickly, by over 25% per year.

Modern construction firms are facing enormous challenges. Demands on infrastructure continue to grow. Around the world, annual investment in transport, energy, water and telecommunications infrastructure totals USD 2.5 quadrillion. This figure will soon rise to USD 3.3 quadrillion per year, just to provide basic amenities to the growing global population. Modern infrastructure, such as smart cities, are becoming increasingly technologically sophisticated – a trend which will continue to increase the demand. The upshot of all this is that there are tremendous opportunities for growth and profit for successful, future-oriented and agile construction companies. By efficiently shaping and erecting modern infrastructure, they can enjoy economic success and create modern, attractive jobs for their employees. Furthermore, through their construction products and working methods in the residential, public infrastructure, transport, energy and industrial sectors, these companies can lay cornerstones for prosperous economies in healthy, liveable and sustainable societies around the world.

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