# How Do Innovative Business Concepts Enable Investment Opportunities in the Complete Construction Value Chain?

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**Abstract**

Our world is changing and the world population is growing rapidly. For all people we need buildings to live, to shop, to work and to enjoy to feel safe and protected. We need a reliable infrastructure to travel, to connect people with people. One of the consequences of growing population is that major cities are incrementally getting bigger. The way we are building needs to change. Conventional infrastructure and living environments are emerging and creating the need for faster, smarter, and lower cost setups. Concepts for Smart Cities and modular housing are born. In most of the local ecosystems, the construction industry is the key driver of growth, wealth, and security. Compared to other industry sectors, the fragmented traditional building industry participants are decades behind adapting to process and lean factory production driven manufacturers. New digital innovative technologies through the Internet of Things (IoT), artificial intelligence (AI), augmented reality (AR), roboting, automatization, and new materials can help to make the required changes. Pioneers, Innovation, Software and Technology are reinventing our construction world. It is time to be the change to come. It is time to change the way the world is building. There are significant investment opportunities in the complete construction value chain through innovative start-up companies. These entrepreneurs and start-up founders will use technology, data, and engaged people to drive the change in the global construction market.

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## 1 Introduction to the Global Construction Market

The construction industry entails architectural—civil—and other engineering services, as well as the physical process of erecting buildings and infrastructure projects, including all products and services required. The construction industry spending worldwide amounted to 11.4 trillion U.S. dollars in 2018. It is also expected that construction expenditures will reach 14 trillion U.S. dollars in 2025 (Wang 2017).

The construction industry is representing more than 13% of the global GDP and is the largest consumer of raw materials and plays a major role in every local economy. There is a close link between spending in construction and growth of the national economy. Project—time—and cost controls are the key performance indicators of success. The industry is very diversified and the production methods differ significantly from the so-called industrial production. The traditional way of building has no future as their productivity increase was only 1% per year over the last 20 years, where other industries improve by more than 3%.

The McKinsey Global Institute highlighted ten root causes of poor productivity classified in three different overarching principles (Barbosa et al. 2017).

Principle 1: External Forces
- Increasing project and site complexities
- Extensive regulation, land fragmentation, and the cyclical nature of public investment
- Informality and potential for corruption distort the market

Principle 2: Industry Dynamics
- Construction is opaque and highly fragmented.
- Contractual structures and incentives are misaligned.
- Bespoke or suboptimal owner requirements.

Principle 3: Firm-Level Operational Factors
- Design processes and investment are inadequate.
- Poor project management and execution basics.
- Insufficiently skilled labor at frontline and supervisory levels.
- Industry underinvests in digitization, innovation, and capital.

The construction industry can get closer to increase their productivity by improving the dynamics and quality of the complete value chain.

## 2 What Is the Construction Value Chain?

The value chain of the construction industry is composed of distinct stages—raw material, building material, construction design, construction project production, conversion, demolition, and recycling. In order to bring a project to function and

realization significant interactions between each process stakeholder are required. In some assignment there are more than 100 companies involved. As every building and infrastructure project is different, there is a unique project-based nature of relationships along the value chain, resulting in a highly fragmented industry structure.

The McKinsey Global Institute identified potential global productivity improvement of the external forces by reshape regulation and raise transparency. Industry dynamics could improve their cost structure by 17% through better collaboration and contracting as well by improving design, planning, and engineering. The Firm-Level Operational Factors do have the biggest impact on improvements by more than 20%. There are four areas identified:

1. Procurement and supply-chain management
2. On-site execution and management
3. Using digital technology and smarter building material
4. Improving the skills of the workforce

We are not building fast enough, we are not building bright enough, people and technology can help to close the gap. Human beings are the heart of change across cultures, languages, and regions.

## 3 How Is the World Population Developing?

At about 8000 years before Christ, around 5 million people were living on earth. Until Christ was born, the population growth rate per year was not more than 0.05%. By the eighteenth century the world population reached 1 billion and by the time of the industrial revolution in 1930 the second billion was reached. The growth rate got faster while the time horizon for the next billion was getting shorter. A population of 6 billion was reached in 2000. It is expected to reach 8 billion by 2027. Furthermore, the world population is set to reach 10 billion by 2057 (United Nations 2019). Asia, Africa, and Latin America are the primary drivers of growth.

The constant growth of the world population generates a growing need for housing, dwellings, and infrastructure projects. Next to population growth there are trends that are describing important changes in areas of society.

## 4 Globally, What Are the Major Impacting Trends on Construction?

1. Wealth will be generated mainly in cities. People are moving to cities for improved personal, social, and economic possibilities.
2. In the last 50 years the household sizes have shown significant declining trends. The United Nations informed that the average household size across the globe ranges from 2 to 9 persons per household. Small average household sizes, of

fewer than three persons per household, were found in most countries of Europe, Japan, and Northern America. Largest household sizes are found in Senegal and Oman, averaging 9 persons. The trend is that household is getting smaller all over the world.

3. Of the world's two billion households, approximately 15%—or 300 million—are one-person households. Among European countries of 40% or more are reported in Denmark, Finland, Germany, and Norway. Moderately high levels of one-person households are also observed in Japan (32%), the United States (28%), and Australia (24%).
4. There is a global shortage of skilled construction workers. The lack of skilled workers has become a growing issue as the ageing, technically experienced workforce that has been relied upon for the last few decades are heading into retirement and no new people want to learn these professions.
5. In the year 1937, Toyota started to develop the "just in time" concept for the Car manufacturing industry. In 1978 the Lean production theory was published in Japan and 10 years later translated into English. During the 1990s the Car industry started to establish lean manufactory. In 1993, the IGLC,[1] an international network of researchers from practice and academia in architecture, engineering, and construction (AEC), was founded and the first ideas of Building Information Modelling (BIM) were launched. After the millennium (year 2000) most of the other industry producers started to establish lean production models in their processes. The building industry is significant far behind.
6. The population is getting older. The ageing Society is recoding the economy, which will become apparent in the coming decade. People in the second half of their life have a different view and different needs on performance, innovation, and growth than younger generations.
7. We live in a global network. Everyone is connected with everyone and everything. The interaction between people and technology and the handling of new opportunities will change our social systems. Now it is important to use the enormous potential correctly and develop new business and revenue models.
8. In our complex world, knowledge is fluid, which is why implicit skills that allow us to be agile and respond to change are in focus. Holistic, systemic thinking, context formation and observation become core competencies as well as deeply interpersonal qualities in our knowledge culture.
9. Through new digital and innovative technologies like GPS, the Internet of Things (IoT), artificial intelligence (AI), augmented reality (AR), roboting, and automatization the construction industry has the necessary tools which are required to overcome the high complexity and improve productivity.

[1] http://www.iglc.net/

## 5 Is the Technology Breakthrough There?

In 2019, KPMG initiated a survey on the global construction Survey (Armstrong and Threlfall 2019). The majority of participants acknowledged the importance and impact of technology and innovation, but few were adopting it significantly, with even fewer reaping the benefits.

MGI's productivity survey also indicated that the biggest barriers to innovation by construction companies are underinvestment in IT and technology more broadly, and a lack of R&D processes (Barbosa et al. 2017).

We are at an early stage of lean manufacturing and at a very early stage of digital transformation of the construction industry. Looking at the global trends and the need of human beings, we can see that the fast transformation is more than needed. We need the change now. The digital revolution touches construction companies, as well as every participant in the value chain and is creating a massive potential for new business models, new products, and services through innovation. At present, globally there are more than 1.000 relevant start-ups in the construction industry focused on analyzing newly appearing technologies to push the transformation. Most of them are based in the United States, others are scattered all over the world. These start-ups are driving new technologies and some of the most relevant and influential initiatives are introduced below.

### 5.1 Smart Building Material and Green Technology

The much awaited and anticipated revolution in construction is gaining momentum. Researchers and various institutes are taking construction material—and product technologies to the next level. Developments in construction materials has been intense and has managed to offer a very convincing answer to the burning question of how modern construction materials could look like in the near future. A selection of the most interesting start-ups from Germany, Austria, Norway, and the Netherlands are giving answers.

#### 5.1.1 Interpanel GmbH

The interpanel GmbH[2] is producing and selling a unique product technology which combines cooling, heating, acoustics, lighting in one prefabricated, modular and ready-to-install solution for buildings. The company was founded in 2016 in Crossen, Thüringen, Germany. interpanel is spin-off of the Fraunhofer Institute.

The global demand for room space cooling increases exponentially due to global warming, higher comfort requirements and economic development. The prevailing principle is an often inefficient, unhealthy, and noisy air conditioning. Due to a lack of regular maintenance, appropriate sizing and installation AC leads to health

[2] http://www.interpanel.com/

problems and discomfort. Studies resulted in a discomfort rate of up to 60% (VBG 2018). Discomfort leads to increased labor costs and reduced productivity.

Interpanels technology cools the room by absorbing thermal radiation, guaranteeing optimal comfort with zero draft. As first of its kind the radiant cooling functions below the dew-point of the ambient air. Due to the high cooling capacity this decreases the necessary covered ceiling area by up to 70% compared to conventional systems. The surface can be activated as human-centric surface lighting system for workspaces. To reduce noise all panels are acoustically equipped. As a result, the essential room climate user needs are covered with one solution: heating, cooling, light, and acoustics. In addition, smart controls and sensors are used to generate data for customers. This automatically optimizes the systems performance. The data is accessed via app. The interpanel solution enables significant lower greenhouse gas emissions, reduced building complexity, and highest flexibility.

Team members are Mr. Alexander Buff (CEO) who is essentially responsible for marketing, sales, IP and process and product improvements. Mr. Daniel Himmel (CFO) handles financing, sales, investments, and legal. Mr. Dominik Donderer, (CTO), production—quality—and product management. Mrs. Andrea Keisers (COO) takes care on process documentation, sales, database maintenance, and operational project management. The interpanel product integrates the functions of cooling, heating, human-centric light, and acoustic absorption in a multifunctional ceiling-sail solution. The "acoustically effective climate light" is the only surface cooling system that is free of condensation water and drafts and offers reliable, healthy and quiet high-performance cooling even in hot summer months. The interpanel technology was developed in cooperation with the Fraunhofer Institute for Building Physics and is patented worldwide. Interpanel is not only presenting a product innovation but as well the complete company is fully digitalized and using innovative lean management concepts, which enables them an early stage profitability. All product components are standardized and designed that construction projects are delivered with module dimensions.

All operational processes are mapped through fully digitized workflows in cloud-based ERP systems. The consistent database gives a complete overview of all-important processes in the warehouse, production and CRM from the first day.

The lean decentralized organizational structure supports an intensive relationship with suppliers and customers. Customers are in focus by every member of the management team and presentations and meetings are held and accessible online. The constantly updated activity documentation is an internal knowledge and process database creating transparency and clarity.

Interpanel is currently active in the mid- to high-end construction sector with a focus on office and commercial properties. Development opportunities are in the area of product diversification and innovative developments in new product areas like medical facility buildings and global expansion.

### 5.1.2 Nuki Home Solutions GmbH

The Nuki Home Solutions GmbH[3] provides smart home solutions and makes access controls smarter and physical keys irrelevant. Nuki is based in Graz, Austria and was founded in 2014 by Mr. Martin Pansy.

The company aims to make a change from standard physical keys to access controls based on technology. They believe in the power of mobile technology innovations and use it to facilitate our daily lives. Nuki turns a smartphone into a smart key in only a few minutes. The Smart Lock is mounted on the inside of the existing door lock and has or requires permanent Internet access. The smart door lock delivers maximum convenience to its customers. By using Bluetooth, Nuki opens the entrance door automatically as soon as an authorized person approaches and closes the door at the push of a button, when the building is left.

### 5.1.3 Airthings

Airthings[4] designs and sells digital radon detectors and was founded in 2008. The Management Team Mr. Øyvind Birkenes (CEO), Mr. Koki Yoshioka (COO), and Mr. Erlend Bolle (CTO) are based in Oslo, Norway. Airthings uses accurate technology to create user-friendly digital radon detectors. An estimated 20,000 people die from radon exposure every year, and it is the second leading cause of lung cancer after smoking. The primary customers are homeowners living in radon-prone areas in the United States, Canada, and Europe. Homeowners can use their device to see if they are at risk of high radon exposure. Radon is a radioactive gas that seeps into the foundation of many homes. Airthings also aims to replace traditional charcoal detection devices that are cumbersome, need to measure for months, and then have be sent to a lab to obtain any results. They also differentiate themselves from their competitors through better build, quality, and design.

### 5.1.4 Breeze Technologies

Breeze Technologies[5] provides air quality sensors as well as data and analytics services. The company is based in Hamburg, Germany and was founded in 2015 by Mr. Robert Heinecke (CEO), Sascha Kuntze (CTO). Breeze Technologies pushes the limits of environmental sensor development. Their small-scale air quality sensors can measure common pollutants like carbon and nitrogen oxides, ozone, particulate matter and many more. Their competitive price point allows for new applications like smart air quality management in a buildings or large-scale environmental sensing in your urban environment. Their environmental analytics cloud platform gathers real-time data from Breeze Technologies air quality sensors as well as external data sources. Based on machine learning and big data technologies, they use their proprietary Adaptive Cloud Calibration Engine to increase data reliability and accuracy. Their cloud platform allows to achieve an arbitrarily high data resolution

[3] http://nuki.io/de/

[4] http://www.airthings.com/

[5] http://ww.breeze-technologies.de/

and can assist facility management, environmental scientists and even municipality management and governments in understanding air quality, its influences and how to improve it.

### 5.1.5 Field Factors

Field Factors[6] is a developer and supplier of rainwater management solutions for urban applications, with special attention to spatial quality. They are a water technology provider, founded in 2016 in Delft, the Netherlands. Mrs. Karina Peña (CEO) and Mr. Wilrik Kok (CCO) are the founding partners and Management Team with the vision to restore the natural water cycle in cities. With an integral approach, Field Factors delivers innovative nature-based solutions for on-site water management, which guarantee high performance and reliability. They have developed Bluebloqs Technology, a circular water system for rainwater treatment, storage, and reuse. Bluebloqs can be applied to ensure green parks, playable sporting pitches, and good quality water for industrial use. Field Factors works with architects and construction teams on urban development and construction projects in the private and public markets in Europe. Installations are done by selected partners with infiltration and recovery systems competences.

## 5.2 Artificial Intelligence, Data Analytics, and Internet of Things

Huge improvements by a structured on-site execution are possible. Using a precise planning process to ensure that key activities are achieved on time and on budget. The use of integrated planning tools will at least achieve 50% increase in project's efficiency. Next is the reshaping of relationships and interactions between all stakeholders like owner, architects, contractors, and subcontractors agreeing and executing regular performance meetings with additional forward-looking plan metrics to identify and reduce variance is critical, ensuring that all preworks have been completed in time. Lean construction manufacturing with the principles to reduce waste and variability need to be established. To change from processes that rely on command-and-control to a more responsible holistic operating system with educated and reliable participants. The high complexity of projects requires an operating approach that integrates technical, logistical, and management competences to maximize resources.

There are some very exiting start-ups representing jobsite construction management mobile software and AI platforms to increase speed, quality, communication, and collaboration between all stakeholders.

[6] http://fieldfactors.com

### 5.2.1 Fieldwire

Fieldwire[7] offers the easiest way for construction companies to stay organized on their jobsites. It is a construction field management platform which connects owners, architects, engineers, general and specialty contractors, and suppliers together in real time.

Fieldwire's Headquarters is based in San Francisco, California, USA. Fieldwire has a regional US office in Scottsdale, Arizona, an international office in Paris, France, and is considering an additional office in the JAPAC region. Mr. Yves Frinault (CEO) and Mr. Javed Singha (COO) are the founding partners. Since founding the company in 2013 Fieldwire has supported more than 500,000 projects active in more than 100 countries with more than 2000 paying customers in 13 local languages. The Fieldwire platform is helping construction companies of all sizes by empowering clear communication on projects. With its easy-to-use mobile application, Fieldwire saves each user 1 h every day by enabling more efficient information sharing onsite. Fieldwire's key features include plan viewing, task management, document control, custom forms, progress photos, instant messaging, reporting, and more—all accessible from one place. Fieldwire is venture-backed by top investors in the industry and is already transforming the way dispersed teams communicate and collaborate on projects.

Fieldwire's construction management software is a fully featured blueprint management solution, so people in the field can view, edit, and share drawings. The construction app makes it easy for everyone to use the latest information and drawings. It is a paperless approach, which renders the need to print new paper copies useless. You can track changes and record your markups and verify with photos and videos. After changes are done, you will receive the latest updated plan as auto-hyperlinking in and real-time sync.

Fieldwire's mobile and web-based construction management software connects field and office teams and gives everyone on the jobsite the tools to execute day-to-day work. Through real-time communication the tools are helping to accelerate decision-making and resolution. These improve craftsperson productivity in the field by putting the information they need right on their phones.

Fieldwire's construction scheduling software focuses on the day-to-day execution of the project plan, bringing both speed and structure to the entire team. Organize, assign, and distribute work from any device while making sure nothing falls through the cracks. Easy crew scheduling by coordinating all upcoming items via a Kanban priority and calendar view. Accurate progress tracking. It is possible to dispatch work to each specialty contractor.

The punch list app adds both speed and structure to the closeout process. It allows to run a better walkthrough process and assign work directly to the people responsible for getting things done. It automatically generates PDF reports and enables sharing them with the project team, owner, or architect with the result of faster closeouts.

[7] http://www.fieldwire.com

### 5.2.2 INDUS.AI

INDUS.AI[8] is an Artificial Intelligence Platform for Construction based in San Francisco, California, USA and in Toronto, Canada founded by Matt Man (CEO) and Navin Kaminoulu (COO) in 2017. The company has clients globally in Hong Kong, San Paulo (Brazil), and the continental United States and Canada.

The INDUS.AI's platform enables developers, project managers, and general contractors to optimize labor, equipment, and materials deployment on commercial construction projects. INDUS.AI is an advanced construction intelligence solution provider, who enables real estate investors, owners, developers, Architects and general contractors to have real-time visibility and actionable insights into all activities, productivity, and risks at their construction sites. They are enabling active proactive monitoring with continuous (1) live site streaming by permanent cameras (including safety and intrusion alerts); (2) artificial intelligence by computer vision (Truck analysis, material arriving, data storage) and machine learning; and (3) with real-time dashboards, predictions (forecasts) and reports (Truck and stuff reports, claim reports) detecting both anomalies and progress. These videos show how INDUS.AI captures, interprets, and analyzes video streams and time-lapse images and turns them into actionable insights. Understand the unit production rate for each trade and compare it to your planned assumptions, track the construction progress and predict whether the construction is on schedule.

Labor analysis for contractor and subcontractor coordination. Get ahead of resource loading and timesheets. Track progress against your Building Information Model (BIM). Ensure that your site and workers are compliant with all safety standards. Track equipment uptime to better manage schedule dependencies. Track and automatically collect construction data on material. Track material arrival and departure insights for project cost controls. Clear visibility in prefab quality and production.

### 5.2.3 Building Radar

Building Radar[9] empowers companies to discover and win potentials building projects through digital tools. By that their customers can realize new market opportunities. Building Radar informs its customers about construction projects worldwide at a very early stage. State-of-the-art AI technology is searching in the internet around the clock and customers are able to find new and existing construction projects before their competitors and are able to pitch first. With the help of Building Radar, customers are informed at an early stage about activities in the construction industry and can thus use this opportunity to position their products and services first.

Building Radar was founded in 2015 by Mr. Leopold Neuerburg (MD), Mr. Paul Indinger (MD), and Mr. Raoul Friedrich (CPO). Member of the management team is Mr. Julian Scharf (COO). The team is supported by 45 employees. Customers

[8] http://www.indus.ai

[9] http://www.buildingradar.com

are companies and individuals whose products or services are needed throughout the construction value chain. Similar services are already offered, but on a manual basis only rather than by machine. In General, manual information are much later available and not scalable. A search algorithm searches in real time the Internet for information on new construction projects. Every day, hundreds of thousands of websites, online newspapers, and information portals (for example, companies involved in construction, such as architects or engineering offices, public bidding platforms, local news sites, architecture blogs, etc.) are searched for new construction projects. The information is extracted using Machine Learning, Data Mining, and Natural Language Processing algorithms. More than 100,000 sources will be generated daily, resulting in approximately 5000 new projects per day globally. Another product line is the new digital information tool: Market Intelligence generates information that updates users about current market trends and movements. This information usually represents another competitive edge for their users. The next step will be the international expansion, with branches in the United States and the United Kingdom and new product development to enlarge their service offering.

### 5.2.4 bGrid

bGrid[10] is a technology and innovation company based in Amsterdam. Mr. Wouter Kok (CEO) founded the company in 2015. bGrid develops, markets, and sells smart building products and services that use state-of-the-art communications technology, with focus on controls, remote monitoring, and "Internet of Things" solutions. To support the delivery of these products and services, bGrid develops mobile devices and sensor units, data management systems, data processing algorithms, and data interfaces. bGrid works in cooperation with international technology partners and integrators, and executes projects for commercial real estate, education, airports, hospitals, laboratories, and other buildings.

The bGrid Smart Building Solution is an answer for intelligent buildings. A network of bGrid Nodes senses everything that happens in the building and enables fast accurate positioning of people and assets. The bGrid Smart Building Solution is open enough to connect and communicate with everything in your building from the lighting and climate system to the coffee machines and even people through their smart devices. It also enables controlling light, climate, blinds, etc. based on the collected and analyzed data. The open API enables third party smart building hardware and software developers to easily connect to bGrid and develop new innovative building applications.

### 5.2.5 reINVENT Innovation GmbH

The reINVENT innovation GmbH[11] simples communication and planning processes for construction projects via a central digital platform. They are based

[10] http://www.bgridsolutions.com

[11] http://www.re-invent.io/

in Munich, Bavaria in Germany. They offer a software platform to connect all major parties during and after construction. It is their mission to redesign all customer processes with digital solutions for communication, data transfer, and documentation to generate significant cost and time savings for building contractors and project developers. Mr. David Uhde (CEO) and Mr. Julian Stieghorst, Mr. Valentin Rüchardt (CTO) and Mr. Christian Brachert are representing the founders and the management team.

## 5.3 Building Information Modeling (BIM), Virtual (VR) and Augmented Reality (AR)

Building Information Modeling (BIM) describes the way in which the entire value chain of the construction industry is interconnected, if planning, execution management and demolition of buildings are using BIM software. All relevant building data are digitally modelled, combined, updated, and recorded. The building is also geometrically visualized as a virtual 3D model. Benefits are significantly improved quality of data, as they all go back to a common database and are constantly synchronized by all involved with immediate and continuous availability of all current and relevant data. This results in a significant improvement on how to exchange information and coordination throughout the life cycle of a building.

Whether architects, planners, or building owners, all benefit from the possibilities of virtual reality (VR) configurators. With them objects in planning are made accessible and adaptable. This greatly simplifies decision-making, for example in the selection of materials or the layout of the room, and allows early detection of errors before they are costly or even irreversible. The applications only need to be developed once. Then they can be viewed and used from any location with VR glasses.

Augmented Reality (AR) is a computer-aided extension of the perception of reality. This information can appeal to all human sensory modalities. Visual presentation by supporting information, such as images or videos with additional computer-generated information or virtual objects by means of fade-in or overlay. AR is used to help with complex tasks such as building construction, industrial applications, navigation, digital cameras, geology, architecture, simulation, and learning.

### 5.3.1 Finalcad

Finalcad[12] provides Collaboration platform as mobile apps and predictive analytics that helps all project's stakeholders fix issues found on the building process. Mr. Jimmy Louchart (CEO), Mr. Joffroy Louchart, and Mr. David Vauthrin founded the company in 2011 in Paris, Ile-de-France. They already helped more than 24,000 projects in 35 countries with 9 local offices and keeps on advancing the

[12] http://www.finalcad.com/

digital transition of the construction industry. Finalcad is focusing on the segments buildings, infrastructure, and energy. It also wants to expand its activities for companies working in other industries. Their vision is based on lots of hours spent on the field, people within the company who are coming from the field in their past professional experiences. This vision is to facilitate the construction with their software, AI analysis tools, and their people. Finalcad offers a guide along the complete construction cycle by Mobile App for site and field engineers, by Web App for the construction site for projects managers and an Analytics App for the general management and project lead. Finally, you will have a complete BIM model with all drawings and information.

Finalcad helps its customers at any stage of their project. Some use cases are:

1. Defect management during and after the construction
2. Digitalized Quality controls
3. Progress follow-up during the whole construction
4. Improved proactivity and reactivity with Health and Safety (H.S.E.) matters

Defect management can easily add observations directly onto drawings (architect, plumbing, technical drawings), assign defects to companies and trades and enrich observations with pictures, comments, and schemes. Track the defect solving rate via a validation workflow. Generate reports from your mobile app or from your web-app. Send your list of defects to the right persons with our PDF and Excel reports. Get a site overview of your defects through the dashboard. With this tool time savings and quality increases in real time are the biggest benefits. Digitalized quality control uses all control forms from the site by using templates. Localization of control sheets on drawings or on a BIM object (checklists, measures, pictures) and get signature from anybody on site or office. Track the whole list of controls from the dashboard. Get real-time information about your team's progress with drawing elements that need to be done based on your daily production. Assign them to the team. Add details about each element (concrete type, element type, openings). Get an overview of the potential orders. Score the daily progress and add information such as concrete consumption, teams, number of hours, etc. Get a weekly progress report and export all data in order to compare progress with planning. Automatically calculate productivity ratios. Capture any field incident, share it instantly and record all safety events and identify risks to take preventive actions. Stay informed about all safety matters via real-time notifications. Automatically generate safety reports to measure the incident rates. Monitor and improve continuously to reach a zero-accident rate.

### 5.3.2 Matterport

Matterport[13] develops and operates cloud-based platform that enables users to create cloud-based 3D and virtual reality models of real-world spaces that can be experi-

[13] http://www.matterport.com

enced, changed, and shared online. Its 3D model allows people to walk through, modify, and share digital environments on devices, such as laptops and iPads. Matterport also provides Matterport Pro 3D camera to capture visual and spatial data and the appearance and dimensions of a space, Matterport Cloud, for cloud hosting and processing, Matterport Spaces for playing web player, and Matterport 3D player, a web-based viewer that enables users to see and navigate through their 3D model. It also offers 3D Showcase that enables users to navigate and visualize homes and other buildings with multiple floors. Matterport serves home improvement, furnishings and decor, property insurance, real estate management, real estate photography, construction management, hotels and vacation rentals, retail space planning, forensics animation, travel, engineering and construction, public and private security, and other industries. Mr. David Gausebeck (CTO), Mr. Matthew Bell, and Mr. Michael Beebe founded it in 2011, with its headquarters in Sunnyvale in California. Next to David the members of the Management Team are Mr. RJ Pittman, (CEO), Mr. Chris Bell, (CMO), Mr. Dave Lippman, (CDO), Mr. JD Fay (CFO), Mrs. Jean Barbagelata (CHRO), and Mr. Jay Remley (CRO). Additional offices are in Chicago, New York and London.

### 5.3.3 IrisVR

IrisVR[14] is the leading software for immersive design review and collaboration in virtual reality. The company was founded by Mr. Shane Cranton (CEO) and Mr. Nate Beatty (CTO) in 2014 in New York, USA. It is used by BIM and VDC teams, design firms, and engineers who coordinate 3D models and implement design and construction processes. Because IrisVR integrates with Revit, Rhino, Navisworks, SketchUp, and other 3D tools out of the box, you can instantly create an immersive VR experience that allows you to present to clients and work more effectively with your team. IrisVR offers a desktop product called Prospect that works with the HTC Vive and Oculus Rift and Windows MR headsets. Prospect makes it easy to host model coordination and QA/QC meetings in a true-to-scale environment. Quickly catch clashes, spot issues, and solve problems with Prospect's built-in tools before they make it onto the job site. Driving hours to the job site and screen sharing kills productivity. Prospect streamlines collaboration by connecting remote teams around the globe in a true to scale environment. Keep the team present and productive with Prospect. A mobile product called Scope that is compatible with the Samsung GearVR, Google Daydream, and Cardboard. Both products are available for free evaluation at www.irisvr.com IrisVr enhance BIM and VDC workflows.

### 5.3.4 XYZ Reality

XYZ Reality[15] is supporting the construction industry with a unique Augmented Reality solution that is able to reduce construction costs by up to 20%. Users are able to walk on site and view their 3D BIM Model, in context, to mm accuracy,

[14] http://www.irisvr.com

[15] http://ww.xyzreality.com

using Augmented Reality. No more disputes, no more out of tolerance errors and real-time validation. The company was founded by Mr. David Mitchell (CEO), Mr. Murray Hendriksen (CTO), and Mr. Umar Ahmed (COO) in London, UK in 2017.

## 5.4 Robotics, Drones, and 3D Printing

Robotic technology provides the construction industry with many opportunities and advantages. Automating processes with increasing productivity, robotics is being used to get work done cheaper, fast, and with a higher quality than manual labor can do. With drones the construction site inspection is easy to monitor. Structured progress monitoring understanding the status of projects. Easy-to-use tools enable measurements and annotations. Communication and getting information by drones are important factors which increase efficiency and reduce labor cost as well you improve the overall security.

A 3D-printed house can be a prefabricated house that can be manufactured off-site or produced on the construction site. With a 3D printer static constructive structures of the house like frame are produced, as well as the walls and the cover construction. Layer-by-layer, using 3D printing technologies entailing a big robotic arm with a nozzle that extrudes specially formulated material, the structures are created. All other building elements, including doors, windows, stairs, flooring, tiles, plumbing and many other elements will be installed in the factory. The advantages of 3D printing a home are the low cost and high speed in which the frame can be built. It is a very sustainable green way of building, as you do not produce any waste. 3D printers today are not limited to concrete but can be used to print metal which the following company is presenting.

### 5.4.1 MX3D

MX3D[16] is a highly innovative company that developed a groundbreaking additive manufacturing method based in Amsterdam, The Netherlands. MX3D was founded in 2014 by Mr. Gijs van der Velden (CEO), Mr. Tim Geurtjens, and Mr. Joris Laarman. Next to Gijs there are Mr. Jelle van Kleef (CTO) and Mr. René Backx (CCO) part of the actual Management Team. MX3D developed a groundbreaking additive manufacturing method with robots (WAAM, Wire Arc Additive Manufacturing).

They can 3D print metals and resin in midair, without the need for supporting structure. It looks like they invented a technology, which can be the beginning for a manufacturing revolution. As this technology opens up endless possibilities, the digital design and fabrication are changing rapidly. They are showing that digital fabrication is entering the world of large-scale, functional objects made of durable materials. Their main competences are based on their proprietary software which is guiding the welding robots of the metal 3D printer.

[16] http://www.mx3d.com

What are the main USPs?:

1. Scaling of machines through software.
2. Low capital investment cost and low operational cost.
3. The freedom of producing complex and large components by 6-axis robots.
4. Access to vast library of off-the-shelf metal materials.
5. Most important is that MX3D robots are not bounded to a building envelop and are able to produces and repair big units and parts.

MX3D executes two different business concepts:

1. Printing and manufacturing services for industrial companies (Best practice)
2. Selling and licensing software for other 3D metal printing companies (Scaling competences)

### 5.4.2 KEWAZO

KEWAZO[17] offers a smart scaffolding logistics robot system that transports scaffolding parts in a flexible, cost-efficient, and safe way. KEWAZO has a strong, interdisciplinary, and international team with six co-founders with diverse background, combining broad knowledge in robotics, civil engineering, automation, software and business disciplines: Artem Kuchukov (CEO), Ekaterina Grib (CFO), Alimzhan Rakhmatulin (mechanical engineering), Eirini Psallida (software engineering), Leonidas Pozikidis (electrical engineering), and Sebastian Weitzel (product development). The first pilot projects are running and in 2020 the company aims to begin with the series product sales.

From 2021, they plan to present a 2D solution for the transport in vertical and horizontal directions as well will introduce robot as a service business model (RaaS—Pay-per-use). The patent-pending solution of KEWAZO is a scaffolding logistics robot "Liftbot" that transports scaffolding parts during scaffolding assembly. The solution is composed of robotic modules and rails. The rails are installed on standard scaffolds using standard connectors, which allows for rapid installation. Robotic modules are installed on the rails within several seconds. They move on the rails vertically and horizontally and transport scaffolding parts from the ground to the assembly point just-in-time and just-in-sequence, securing a constant material flow. The proposed system automates the logistics process by employing autonomous navigation and workers detection. Compared to existing solutions the robotic system requires only two workers for operation, is easy to install, and can perform vertical and horizontal transportation of parts. The solution addresses labor shortage, saves at least 33% of labor costs, and increases productivity by 20%. The robotic system also records operational data from the construction site by using computer vision and sensors data. By creating a digital twin of on-site operations, KEWAZO provides customers with better controlling, planning, and suggestions.

[17] http://www.kewazo.com

KEWAZO provides a fully integrated smart solution—a package that contains a robotic system empowered by the data analytics platform. The customers have an option of buying and renting the system. The data analytics platform is offered on the SaaS basis.

### 5.4.3 XtreeE

XtreeE[18] is a large-scale 3D printing system for the architectural and the construction industry with design requirements. They offer collaborative design approaches combined with large-scale 3D prototype manufacturing with concrete, clay, and polymers. The company was founded end of 2015 and is based in Rungis, Ile-de-France in France. Mr. Alban Mallet is co-founder (CEO) and contributes to the design of innovative large-scale additive manufacturing systems. Mr. Alain Guillen and Mr. Jean-Daniel Kuhn, managing directors, make large-scale 3D-printing technologies available in the building and infrastructure sector in France and international as well as service- and rental business. XtreeE's team brings together a vast array of complementary skills and experience, i.e. architecture, civil engineering, robotics, computer science, and material science. This allows the company to master 3D printing's complete production chain, from design to manufacturing, and gives the ability to intervene at every of an architecture or design project. They are active in art and design, developing new products together with their customers as well designing new house concepts.

### 5.4.4 Apis Cor

The company Apis Cor[19] develops mobile construction 3D printers that work in polar coordinates and is originally from Moscow City, Russian Federation founded by Mr. Nikita Chen-iun-tai (CEO), who lives close to Boston, Massachusetts, USA today. They call themselves "robotics in construction" as they 3D print the whole structure right on the site from start to the end. They are working on different new functions like inter-story floors, roof printing, automatic horizontal wall, and on foundation reinforcements placement.

### 5.4.5 Yingchuang Building Technique

First Chinese companies were actively driving the development of 3D-printed buildings. Spectacular are the achievements of the Chinese construction company called Yingchuang Building Technique (Shanghai) Co. Ltd. (Winsun)[20] that 3D printed a 6-story apartment building. Winsun has built more than 400 buildings and developed as well as created new building material which helps to increase speed, quality and reduce cost. Winsun improved the development of new building material like glass fiber-reinforced gypsum board and cement.

[18] http://www.xtreee.eu/

[19] http://ww.apis-cor.com

[20] http://www.winsun3d.com/

### 5.4.6 ICON3D

Another pioneer is the company ICON3D[21] based in Austin, Texas, USA. ICON developed concrete 3D printers as individual robots, the required design and application software as well the advanced concrete material.

### 5.4.7 RedWorks Construction Technologies Inc.

The company RedWorks Construction Technologies Inc.[22] based in Lancaster, California, USA is developing an on-site 3d printing system that only use on-site sources of sand/dust/dirt to create materials that can match the strength of existing masonry. This technology will cut overhead costs, reduce site logistics, and let builders print custom materials without impacting costs or build-time. The founders are Mr. Keegan Kirkpatrick (CEO), Mr. Paul Petros (CDO), and Mrs. Susan Jennings (Building Material Specialist).

## 5.5 Smart and Mobile/Modular Homes

Modular homes production can reduce the construction time by more than 50%. Site construction build houses can take many months to complete, while modular homes are assembled on site only and can be finished between 1 day and 1 week. In a controlled factory environment modular homes are built in sections, or modules, and then transported to the construction site. There, they are installed on permanent foundations and completed.

There are some very exciting start-ups on the way to change the way of construction buildings. Haus.me is based in the Ukraine and in the United States. Mighty Buildings Inc. in the USA as well, where the Project Milestone is founded in the Netherlands and Containerwerk Hall eins in Germany.

### 5.5.1 haus.me

haus.me[23] is the first fully self-sustainable mobile house provider. The portable home does not require an electric grid, propane, natural gas, firewood, or any other fuel. It uses solar energy for heating, cooling, and electricity and it works in both hot and cold climates. The benefits are no energy bills as the house is fully off-the-grid and self-sustainable. As the house will be delivered turnkey no site construction is required and is ready to use. The house is fully automated including operating system and smart home applications. The house withstands hurricanes and earthquakes and is zombie proof and is offered in different models like a family home.

[21] http://www.iconbuild.com

[22] http://www.redworks3d.com

[23] http://www.haus.me

haus.me is an integrated, intelligent, and smart home. The house possesses 24 intelligent subsystems that work together with house AI system to ensure the living safety and comfort. The home self-diagnosis system informs about the problem before it appears. haus.me can be used as a primary residence, a vacation home, a guest house, studio, or income-producing secondary dwelling—like an Airbnb rental—or as an autonomous hotel unit.

haus.me team was founded in 2016 as PassivDom and has years background and deep knowledge in energy-efficient construction, 3D printing, physics, chemistry, IoT, electronics software, real estate marketing, and sales. Julia Gerbut and Max Gerbut are the founders. Sergii Tychyna is the COO of the company. The haus.me business is like SaaS for Construction industry, including new products development, engineering smart IoT systems, logistics, software and cloud cervices. In the next phase they will look for international distributors and investors to build a global business.

### 5.5.2 Mighty Buildings Inc.

The start-up company Mighty Buildings Inc.[24] is located in Oakland, California, USA. Their concept is to build beautiful, affordable, and sustainable modular housing. They developed a 3D printing opportunity to enable a green way of building houses. Through their automation process in a factory, they are able to speed up the building process and are able to reduce cost simultaneously. Actually, they are in a stealth-mode and will inform about their strategic moves during 2020. The founders are Mr. Slava Solonitsyn (CEO), Mr. Alexey Dubov (COO), and Mr. Dmitry Starodubtsev (CTO). At present they have more than 80 employees and are present on Facebook.com and on YouTube.com with video footage.

### 5.5.3 Containerwerk eins GmbH

Containerwerk eins GmbH[25] is building modular homes and offices by using old/used containers. They are designers and create innovative portable housing solutions. They are based in Wasserberg, Germany and are founded and managed by Mr. Ivan Mallinowski and Mr. Michael Haiser. They searched for answers to housing shortages, inexpensive, resource-saving, and contemporary living and therefore introduced the method of using containers. In the interests of the circular economy, ecological and social sustainability, Containerwerk acquires used sea freight containers and refines the corpus into high-quality and inexpensive living space. Convinced and fascinated by the idea of building with disused sea freight containers, they are first dealt with the building block, the “brick” of this architecture, and developed a process that turns a container into a universal, sustainable housing module.

[24] http://www.mightybuildings.com

[25] http://ww.containerwerk.com/

## 6 Conclusion

Globally digital technology and services have affected a number of industries. The traditional construction industry can take the huge advantages of it. Digitalization has finally reached architects, building material producer, contractors and their value chain. And it is about time to get up to speed to use the tools which are available. Most of the contractors still work the same way they operated decades ago. A shift from the physical and manual work to the digital world is extremely beneficial and the construction industry seems to be slowly coming to this realization. Better profit margins, less cost, improve time efficiency, better collaboration and communication with advanced reporting, a higher productivity and a healthier security—digital technology and services are promoting the construction industry on a performance level, it never did before. Implementing it is not a choice, it is a necessity. If organizations are reluctant to innovative change, they will no longer be in business. The innovation train is driving every day faster to reinvent the construction industry, say yes to innovation and remain competitive. Supplementary material for this chapter is provided at www.christophjacob.com.

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