CDTM
CENTER FOR
DIGITAL TECHNOLOGY
AND MANAGEMENT

THE DIGITAL FUTURE OF THE CONSTRUCTION INDUSTRY

TREND REPORT 2018

The Digital Future of the Construction Industry

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INNOVATIONS MANAGEMENT BAU GMBH

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The "Innovationsmanagement Bau GmbH" is a newly founded joint venture of seven medium-sized construction companies.

The partners thrive to identify, generate, accelerate, and distribute innovations in the construction industry based on multidisciplinary and cross-organizational collaboration.

In 2017, the "Innovationsmanagement Bau GmbH" partnered together and managed a turnover of more than one billion Euro with about 3500 employees covering most business areas of the construction and real estate sector.

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CDTM CENTER FOR DIGITAL TECHNOLOGY AND MANAGEMENT

A project of the Center for Digital Technology and Management (CDTM)

The Center for Digital Technology and Management (CDTM) is a joint, interdisciplinary institution for education, research, and entrepreneurship of the Ludwig-Maximilians-Universität (LMU) and the Technische Universität München (TUM).

It offers the add-on study program „Technology Management" for students from various backgrounds, which provides students with tools and knowledge at the intersection of business and digital technologies.

The entire trend report was written by CDTM students under the close guidance of research assistants. For more information about the CDTM and its related projects, please visit www.cdtm.de.

PREFACE OF THE EDITORS

As Herman Kahn, one of the founding fathers of modern scenario planning, nicely states, it is tremendously important for strategy and policy makers to get a deep understanding of possible future developments in order to be prepared for them.

The Center for Digital Technology and Management (CDTM) aims to empower innovators of tomorrow. It is our mission to equip our students with the tools and knowledge they will need to become responsible leaders, who actively shape their future environment, rather than only react to changes.

This trend report is the result of the course Trend Seminar, which is part of the interdisciplinary add-on study program "Technology Management" at CDTM. About 25 selected students of various disciplines, such as Business Administration, Economics, Psychology, Computer Science, Electrical Engineering, and others, work together on a relevant topic related to ICT. Over the course of seven intense weeks of fulltime work, the participating students dive deeply into the topic of the Trend Seminar. Working in several interdisciplinary sub-teams, students apply the knowledge of their main studies and learn new perspectives from their team members. They conduct trend research, develop scenarios of the future, generate ideas for innovative products or services, and detail them out into concrete business concepts.

> **"Everybody can learn from the past.
> Today it is important to learn from the future."**
>
> Herman Kahn

We would like to take the chance to thank everyone who contributed and made this CDTM trend report possible:
We want to thank Innovationsmanagement Bau GmbH for supporting this Trend Seminar. Particularly, we want to thank Thomas Donhauser, Michael Thon, Sandro Pfoh, and Christian Philippen for their great interest in the topic, the valuable insights and feedback throughout the whole project, and the collaborative organization and topic definition of this Trend Seminar.

In addition, we very much thank all our lecturers, who shared their knowledge and largely contributed to this project's success:

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Last but not least, we would like to thank the CDTM students of the class of Fall 2018. They put great energy and enthusiasm into this project, which made it a pleasure for us to supervise the course and coach the individual teams.

Gesa Biermann and Philipp Hulm
Center for Digital Technology and Management

PREFACE OF THE PROJECT PARTNER

The construction industry employs around 2.5 million people in Germany and contributes significantly to the GDP and economic stability. Catering to some of societies basic needs for housing, infrastructure, or water and energy supply, we are faced by constantly evolving societal demands. Amongst these are for instance the demand for affordable and future-proof living spaces, as well as for environmentally friendly and resource-efficient buildings that support a low carbon economy, the need for generating sustainable employment while facing a constant increase in regulations or costs, and the expectation to finish buildings on time, particularly when it comes to public construction projects.

However, the business models of the construction industry have not changed much in the last decades and the productivity has barely increased in the last 20 years, both in planning and construction processes. The level of industrial prefabrication is still low and the influence on large producers of construction products is limited.

Digitalization rates, especially on the construction sites, are low compared to other industry sectors. Even though the planning processes became increasingly digital in the last decade and quite some changes are to be expected with a large-scale application of building information modelling (BIM), the challenge still remains to take digital technologies onto the construction sites. Increased digitalization rates, however, could enable long-desired productivity and profitability gains for the industry. Thus, we believe that the construction industry is a very promising market for digital products and solutions and is ready for a "digital revolution".

That's why we were very delighted to be able to partner with the Center for Digital Technology and Management (CDTM) and would like to thank Professor Klaus Diepold for facilitating CDTM partnerships with small and medium-sized companies, to support the "German Mittelstand" in the digital challenges it is facing. In order to assess digital disruptions or change processes, which other industries have already been through, for the construction industry, we had two guiding questions for this year's trend seminar. Firstly, the question of what is going to be built around the year 2050, a rather short to mid-term future given the industry's innovation cycles, and secondly, the question of how buildings are going to be built.

> **"We know the destination, the is way is flexible, please help CDTM!"**
>
> M. Thon, Innovationsmanagement Bau GmbH

Therefore, we were very happy to open our doors to the CDTM and the students to see for themselves what the construction industry is all about, where the specific challenges lie ahead, and that the industry is maybe not just all about bricks and mortar.

This report provides the basis for further innovation activities of the "Innovationsmanagement Bau GmbH" and supports the entire industry, in cooperation with the "Bayerische Bauindustrieverband" (Bavarian Construction Industry Association), to enter a new digital age and broaden the horizons beyond the traditional business models.

We are aiming to drive the development of some of the great business ideas generated during the CDTM partnership in 2018 and beyond, and will provide the necessary framework conditions for interested students and entrepreneurs.

Our thanks go particularly to all the CDTM students of the class Fall 2018 whose complementary skills, energy, and drive fueled an exciting journey and who inspired us to lead the way to a digital future of the construction industry.

Our special thanks go to Gesa Biermann and Philipp Hulm as well as Michael Chromik, for their enduring enthusiasm around the digitally undiscovered construction industry and for their continuous support and advice across language and cultural barriers.

In the name of the joint venture partners:

Michael Thon, Thomas Donhauser, Sandro Pfoh und Christian Philippen, Innovationsmanagement Bau GmbH, Munich, October 2018

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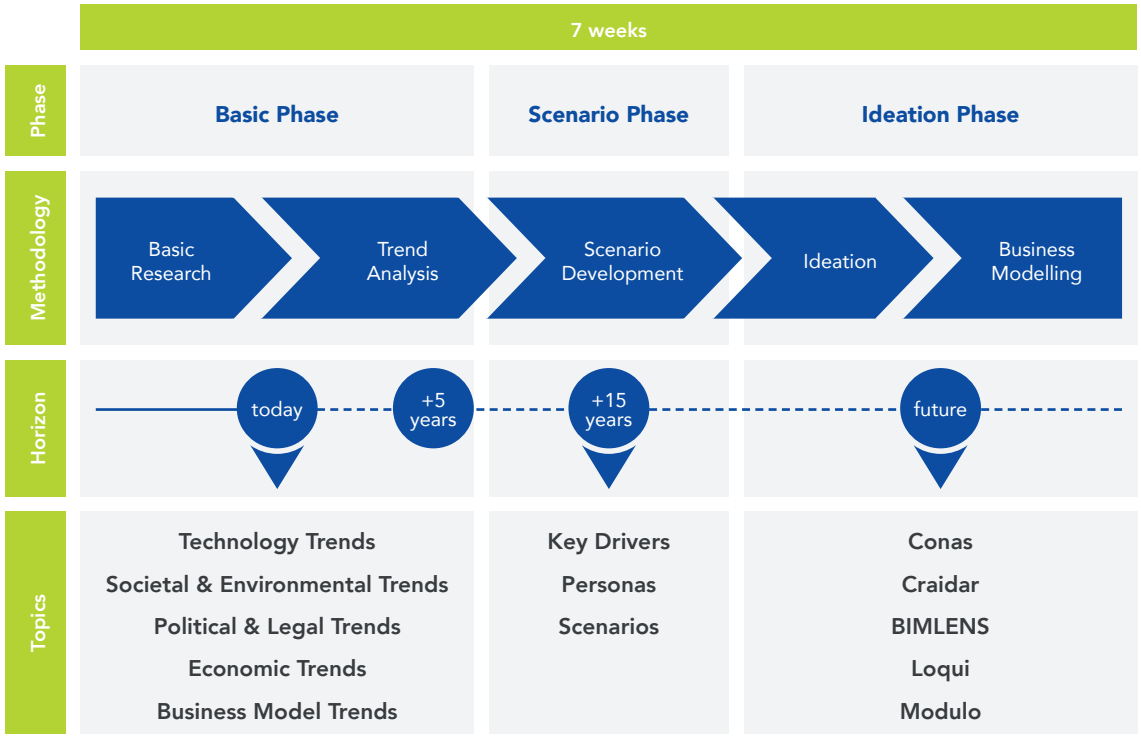
METHODOLOGY

For a given topic that is highly impacted by digital technologies, the Trend Seminar pursues three main goals:

- To analyze the status quo, recent developments and identify important trends
- To develop extreme scenarios of the future, in order to be prepared for upcoming challenges
- To develop future-proof product and service ideas and detail them out into business concepts.

These goals are represented by the three phases of the trend seminar: The Basic Phase, the Scenario Phase and the Ideation Phase.
Twenty-six students, supervised by two doctoral candidates, pursue the Trend Seminar in seven weeks of intensive full-time work alongside their project partner. In each phase, interdisciplinary subteams are formed including students from technology, business, and various other backgrounds to combine versatile ways of thinking.



The **Basic Phase** yields a holistic overview of recent developments and trends in the environment of the overall topic. Based on the commonly used STEP approach (Social-Technological-Economic-Political), the status quo and trends in the fields society & environment, technology, economics, politics & legal, as well as emerging business models are analyzed. Knowledge is gathered by literature research, preceded by a series of input presentations by experts on the topic.

The class is split into five teams, each working on one of the thematic scopes. At the end of the Basic Phase, the teams present their key findings to each other in order for everyone to get a holistic view on the topic to build upon in the following phases.

The **Scenario Phase** builds upon the analyzed trends in order to create four extreme scenarios of different futures twenty years ahead. Driving forces behind developments are identified and specified as drivers with bipolar extreme outcomes. Once specified, all drivers are ranked according to their respective impact on the overall topic and the perceived degree of uncertainty regarding their outcome. Two key drivers that are independent from one another and have both a high impact and a high degree of uncertainty are chosen and, with their bipolar outcomes, used to create a scenario matrix of four extreme scenarios. A timeline for each of the scenarios is created and the scenarios are sketched out using persona descriptions and visualizations. The Scenario Phase starts with a two-day workshop followed by group work in four teams. Teams are newly formed in order to include experts from each subtopic of the Basic Phase in each new Scenario Team.

In the third phase, the **Ideation Phase**, the goal is to develop innovative business concepts, which are then tested against the previously developed scenarios. Within a two-day workshop on structured ideation following the SIT approach (systematic inventive thinking), a large number of business ideas are developed.

Out of these, the most promising five ideas are selected and further developed into detailed business concepts. The business model canvas by Alexander Osterwalder and Yves Pigneur serves as the base structure.

At the end of the seminar, the business concepts are presented to the project partner and guests.

LIST OF ABBREVIATIONS

3D
Three Dimensional

AI
Artificial Intelligence

API
Application Programming Interface

AR
Augmented Reality

BIM
Building Information Modeling

BIY
Build it Yourself

BMVI
Federal Ministry of Transport and Digital Infrastructure

CAD
Computer-Aided Design

CAGR
Compound Annual Growth Rate

DACH
German-Speaking Countries

DGNB
German Sustainable Building Council

DIW
German Institute for Economy Research

ECB
European Central Bank

GDPR
General Data Protection Regulation

GPS
Global Positioning System

HVAC
Heating, Ventilation, and Air Conditioning

ICT
Information and Communication Technology

IoT
Internet of Things

ISO
International Organization for Standardization

LaaS
Living-as-a service

LLC
Life-Cycle Cost

LiDAR
Light Detection and Ranging

LTE
Long Term Evolution

O&M
Operations and Maintenance

R&D
Research and Development

SDK
Software Development Kit

SME
Small and Medium-Sized Enterprises

UAV
Unmanned Aerial Vehicle

VR
Virtual Reality

TRENDS

The following chapter lists current trends that have a strong impact on digital companions in the factory of the future. In accordance with the Basic Phase methodology, trends and related driving forces are structured in five areas: technological trends, societal and environmental trends, legal and political trends, economic trends and business model trends.

TECHNOLOGY TRENDS

INFLUENCES ON THE DIGITAL FUTURE OF THE CONSTRUCTION INDUSTRY

Construction Automation
Digitalization and Data Collection
Augmented Workforce
Visualization
Artificial Intelligence
Remote Collaboration and Communication

TECHNOLOGY TRENDS

Shaping the Digital Future of the Construction Industry

The construction industry is one of the least digitized industries in Germany [1]. Hence, the industry first has to catch up with technology trends which are already implemented in other industries before applying the latest technologies. Two of those fundamental technology trends that should be adapted are the digitalization of existing processes including data collection and the use of suitable software for communication and collaboration. This general digitalization does not only enable the implementation of more advanced technologies in the future, but it is also essential for construction companies in order to increase the efficiency of processes to stay competitive in near future [2]. One example is the requirement for building information modeling (BIM) in public infrastructure projects from 2020 onwards [2]. Additionally, companies can profit from an efficiency increase by digitizing their processes [3].

Once processes, such as communication, collaboration, and data collection are sufficiently digitalized and are not only done analogously, the industry can focus on more advanced technology trends like the automation of processes and the use of wearables and exoskeletons. The automation of processes refers to the use of robots, unmanned aerial vehicles (UAV) and 3D-printers, mainly for the fabrication and building process of construction projects. The use of these devices results in more efficient work, fewer material costs and, most importantly, it compensates for the scarcity of workforce [4], [3], [5]. Wearables and exoskeletons can approach the problem of the scarce workforce by increasing safety for construction workers. On the one hand, exoskeletons physically support demanding tasks and on the other hand, wearables can collect data as an application of the Internet of Things (IoT) in order to prevent accidents on-site [6]. Exoskeletons support the human workforce by making their day-to-day job physically less demanding and therefore less prone to injuries [7]. Altogether, the attractiveness of construction jobs increases with the use of wearables and exoskeletons.

In a further step, high-tech trends such as the use of the visualization technologies augmented reality (AR) and virtual reality (VR) can be specifically applied in the context of BIM. While VR especially adds value in the planning phase, the use of AR has a large potential during the building process. AR can help construction companies to prevent misunderstandings with both sub-contractors and customers. This is of a large impact since changes at the end of the building process are very expensive and a significant pain point for construction companies [8]. The use of artificial intelligence (AI) requires a vast amount of data of high quality. Therefore, this trend will be relevant in an even later step compared to the use of visualization technologies. The increase of efficiency in terms of coordination and productivity of tasks is the main application in this field [9].

CONSTRUCTION AUTOMATION

Automation of Repetitive tasks enables workers to focus on complex duties.

Unmanned aerial vehicles (UAV), such as drones, robotics and additive manufacturing, such as 3D printing, will offer construction companies opportunities to improve efficiency [10].
First, in the 1980s UAVs emerged by spraying pesticides on Japanese rice fields. Since then, the technology advanced and is now disrupting industries from filmmaking to infrastructure [11]. In the construction industry, UAVs can help to assess properties on their development potential or to track progress on construction sites. This is done by comparing the data captured by UAVs with the BIM [12].
Second, 3D printing came up in the 1980s as well, when Hideo Kodama published a paper about it in 1981 [13]. Researchers advanced the technology so that there are multiple manufacturing techniques and printing materials available today. Nowadays it is used in multiple industries, for example the aerospace industry to build jet engine parts [14], [15]. 3D printing is highly effective, if specialized small scale products have to be built – such as in the construction industry [14]. In fact, first houses have been built by 3D printers with the help of robots to move the print head, but there are still some technological hurdles to take to reach product maturity [160], [17].

Facts:

- A survey among mainly North American companies in the construction industry revealed that 37.8% of them experiment with UAVs, while another 10.2% experiment with additive manufacturing [18].
- The global construction market size for business solutions addressable by UAVs amounts to 45 bn USD, which includes flying over a construction site and tracking the progress [11].
- UAVs are already used on construction sites and increasing efficiency [4].
- A shell construction single-family house can be built by a 3D printer in 10 hours while three workers would need 6 days leading to cost reductions by up to 30 [19].

Key Drivers:

- German government increasingly encourages construction companies to use BIM [19].
- The current building processes prevent efficiency increases which can be solved with the help of automation [20].
- Due to physical stress and health security concerns on construction sites, it will become increasingly difficult to attract workers [21].
- Advances in high resolution and light weight cameras and sensors, battery lifetime and autopilot navigation enable advancements in UAV technologies [12].
- Currently, robotic technologies are increasingly finding applications in the construction industry, because they are learning to operate in unstructured environments [20].

Challenges:

- Depending of the application of UAVs, they would film entire construction sites and therefore the workers, which means that privacy issues need to be considered [12].
- In order to use additive manufacturing in mass production, researchers still need to improve on different issues, for example the composition of concrete to let it dry faster [160].
- Robots are capital intensive and therefore pose a financial challenge for construction companies [20].
- Buildings need to be planned with the purpose to build them automated, which needs to be enforced by management [20].
- Robots need to be capable of handling complex and uncontrolled environments on construction sites [20].

Impact on the construction industry:

The automation of the building processes addresses the problem of finding employees and leads to efficiency increases. Automated construction sites are less dangerous and require skilled workers to work with new technologies, which increases the job attractiveness [22], [5]. Furthermore, there are examples of how automation can improve efficiency. Additive manufacturing for example can save up to 60% in material, 80% in workforce and 70% in time [3]. Furthermore, UAVs are able to reduce costs, increase safety and improve data quality on the construction site [11].

DIGITALIZATION AND DATA COLLECTION

Digitalizing Existing Processes and Data to Profit From Technological Progress

It is a generally accepted fact that digitalization has been one of the major drivers behind the increase in productivity taking place in most industries in the past decade. Still, it can be observed that there is a large discrepancy between the rise in productivity in the German construction industry, where this measures only 4.1%, and related industries such as manufacturing, which has improved on average by 34.1% over the last 10 years [3]. Therefore, one can draw the conclusion that it is imperative for construction companies to tightly integrate software if they are to reach similar levels of growth. The conversion of standard processes to a software-based approach represents only a first step towards the goal of digitalization, whereas the next one consists in the collection of data through a variety of sensors. The information about many aspects of the development cycle collected in this way may seem to have little worth on its own, but the advent of sophisticated data analysis algorithms opens up a world of possibilities in the fields of monitoring, prediction, optimization, and automation.

Facts:

- In the German construction industry, 93% of players agree that digitalization will affect every process in their value chain [23].
- Less than 6% of German construction companies fully rely on digital planning tools in their process workflow [3].
- Building materials firms believe there is a lot of potential in digital technology [3].
- In Germany, the call for tenders is already issued electronically for 80% to 90% of public construction projects [3].
- In half of the construction companies in the German-speaking countries (DACH), more than 60% of the employees own a smartphone [2].
- Digital platforms allow savings of around 5% for catalog-based purchases and around 10% in the case of online auctions [3].

Key Drivers:

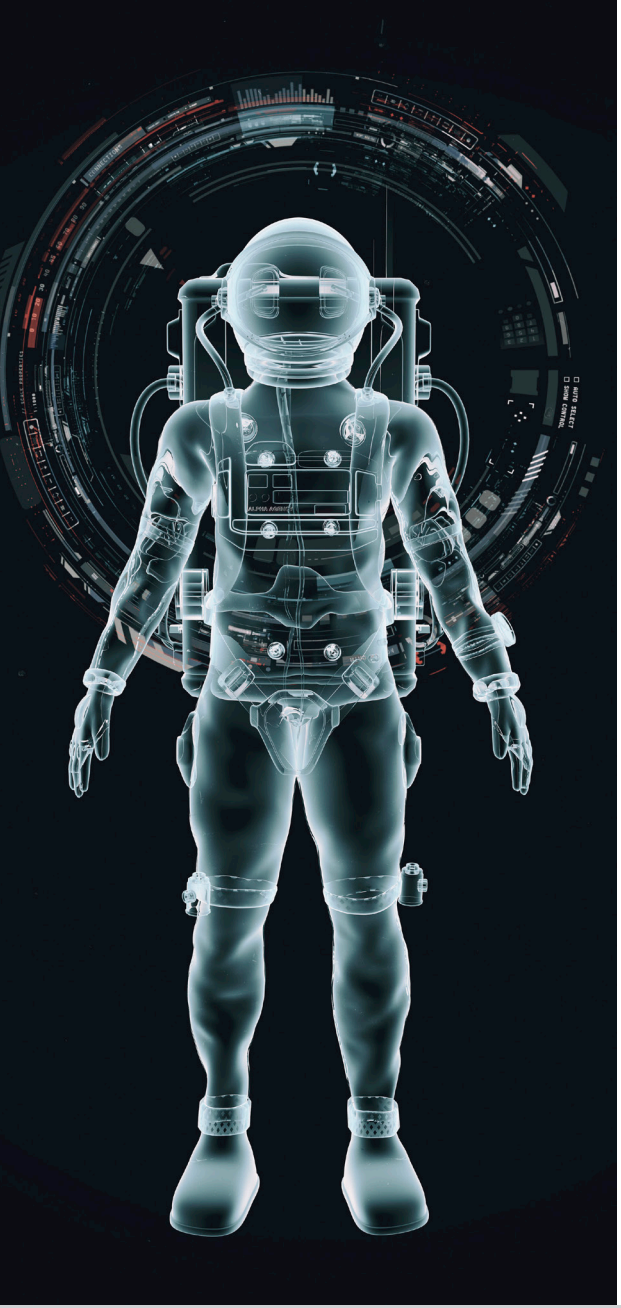
- The EU promotes digital calls for tendering of public construction projects, because of their transparency and efficiency [3].
- Cloud-based mobile apps are favored by the availability of low-cost mobile connectivity [1].
- The emergence of IoT will allow to connect both machines and workers and allow to collect immense amounts of data.
- The German Federal Ministry for Transport and Digital Infrastructure prescribes the mandatory use of BIM in public infrastructure projects as of 2020 and therefore fosters the use of digital technology in the industry [2].

Challenges:

- Defining standardized digital solutions for diverse construction scenarios is a difficult task [1].
- Another challenge is the scaling of software that is useful to construction companies differing in size and sophistication level or only function as subcontractors [1].
- Decision makers in construction are often very skeptical towards the adoption of digital tools believing that this is impracticable due to the uniqueness of each project [1].
- In the short term, there will be compatibility issues between emerging software solutions from different software manufacturers [24].
- Construction sites often experience a lack of reliable and high-speed broadband connectivity [1].

Impact on the construction industry:

Digitalization will influence every part in the value chain. It will redefine the planning process by including more information gathered through IoT devices such as wearables and will make sure that all the stakeholders are aligned with the process [24]. To this end, BIM software will finally substitute paper plans to create "digital twins" [25], [26]. Using digital solutions will help construction managers to easily keep track of the proceedings by reducing their effort drastically [2]. Mapping technologies such as the global positioning system (GPS), light detection and ranging (LIDAR), and photogrammetry will be used for surveying and provide vast information about the building terrain and later the building itself [1]. Lastly, digital solutions will improve customer relationship, by analyzing customer data and offer tailor-made services [2].



AUGMENTED WORKFORCE

Using Wearables and Exoskeletons to Improve Safety and Communication Capabilities

Smart watches, activity tracker bracelets, and AR glasses are typical examples of wearables. An exoskeleton is a wearable mobile machine which supports the muscles of the carrier and therefore enhances his ability to do physically demanding jobs. Wearables are already used in industries like health care, manufacturing, mining, and athletics to monitor and increase the safety [27]. Not only athletes use it to monitor heart rates to gain real-time feedback about their performance [28], but also the mining industry uses proximity warning systems based on GPS to prevent collisions between mining equipment, small vehicles, and stationary structures [29].
Wearables and exoskeletons can be added to the apparel of construction workers to confront the problem of high safety risks typical for this industry [6] and to prevent injuries such as dorsal pain. For instance, the exoskeletons can be applied where workers have to lift heavy machinery and materials [30]. The wearable technologies can cover in an outdoor scenario so that the tracking of the actual position of workers is possible. In addition, wearables provide individual users with useful services and information while they are still able to perform other tasks in parallel [31].

Facts:

- The construction industry has the third most accidents at work [32]. On German construction sites, 104,820 work related accidents happened in the year 2016 [33]
- Exoskeletons have been developed that do not need any motors or batteries, so one can use it all day without charging [30]
- Ford integrated 75 exoskeletons for supporting their workers in 15 factories worldwide [34]
- The robotic exoskeleton sector is expected to reach 1.8bn USD in 2025, up from 68m USD in 2014, with a compound annual growth rate (CAGR) of 39.6% in market share [35]

Key Drivers:

- Work-related injuries in the construction industry are among the highest compared to other industries [36], [32]
- Communication requirements are rising due to the increasing complexity of construction sites [36]
- The workforce has to become more efficient as construction companies face increasing cost pressures [37]
- The unattractiveness of the job leads to a scarcity of on-site construction workers [36]

Challenges:

- Along with the requirement for usability due to the workers' lack of digital affinity [38], the technology has to protect the privacy, personal freedom, technological independence and individuality of workers [39][160]
- The devices have to be robust for on-site usage [36], [24]
- Affordability and scalability are important issues [36]
- High accuracy and update rate of sensors is fundamental for positioning [36]

Impact on the construction industry:

The augmentation of the workforce via wearables or exoskeletons is an opportunity to increase safety and lower the actual rates of fatal and nonfatal construction injuries while simultaneously increasing efficiency through the provision of hands-free capabilities [41]. The usage of digital tools will also help to increase the image of the on-site construction work as nowadays the younger generations are sophisticated with digital technology. Additionally, using wearables and exoskeletons on construction side provides the opportunity to overcome communication issues with for instance natural language processing functionalities embedded in smart bracelets.

VISUALIZATION

Using AR and VR for Building Planning, Execution and Showcasing

Ranging from VR headsets to smartphone applications for AR, visualization technologies have the potential to improve virtually all steps of the construction process. Using VR, architects will be able to intuitively visualize the 3D models of future buildings and show it to stakeholders in order to reduce miscommunication [42]. Similarly, on the sales front, VR will make it possible to showcase buildings before construction begins, helping potential buyers better understand what is being offered [43]. Workers' risks during training with heavy machinery will also be mitigated, as practice will take place in virtual environments [44]. Meanwhile, on the construction site, paper plans will be replaced by direct visualization of the BIM model, which will always be up to date and provide the optimal amount of detail for the tasks at hand.
There are countless novel applications having AR or VR as their cornerstone, but the adoption of visualization technologies has been slow. Still, with the release of devices such as the Oculus Rift and the Microsoft HoloLens at the high end, and Google Cardboard at the low end, these technologies are starting to also be applied in the workplace. A prime example of this is the automotive industry, which has become a front-runner of the field [45], yet the construction industry is not as keen in their adoption of new technologies.

Facts:

- Worldwide spendings on AR and VR are forecast to achieve a five-year CAGR of 71.6% over the 2017-2022 period [46]
- Leaders of the tech industry invest in AR and VR: Google with Project ARCore and Daydream, Microsoft with Hololens, Facebook by acquiring Oculus, and Apple by acquiring Akonia Holographics [47], [48]
- Automotive spendings on AR and VR are projected to reach 12.8bn USD in 2021, with major manufacturers such as BMW and Ford already making use of visualization technologies [45]
- Mobile AR market is expected to reach 1.9bn unique monthly active users by 2022 [49]

Key Drivers:

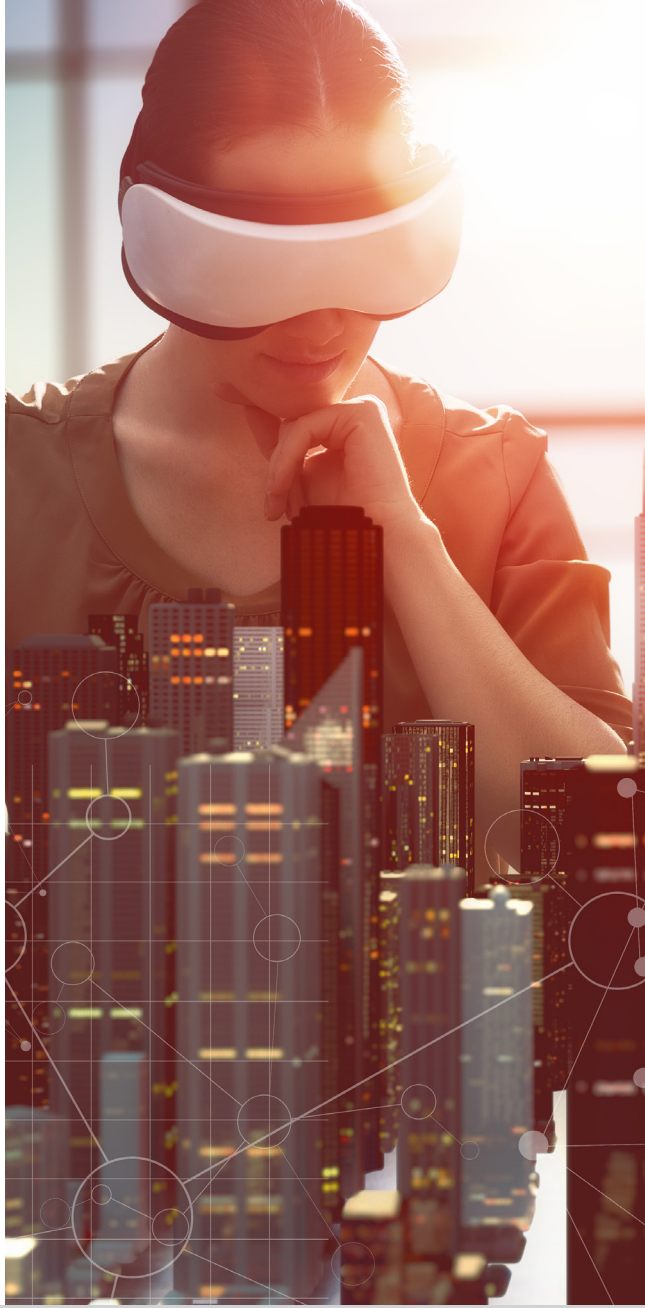
- Displays with very high pixel densities are being developed, improving the visual quality of VR [50]
- The computing power available in mobile devices has been rising steadily, which makes high-quality graphics possible [47]
- Lithium-ion batteries are becoming cheaper, while energy density has been increasing, enabling affordable devices with long battery life
- The increasing adoption of BIM, partly due to regulations, means that 3D building models will be available for use with visualization technologies [19]

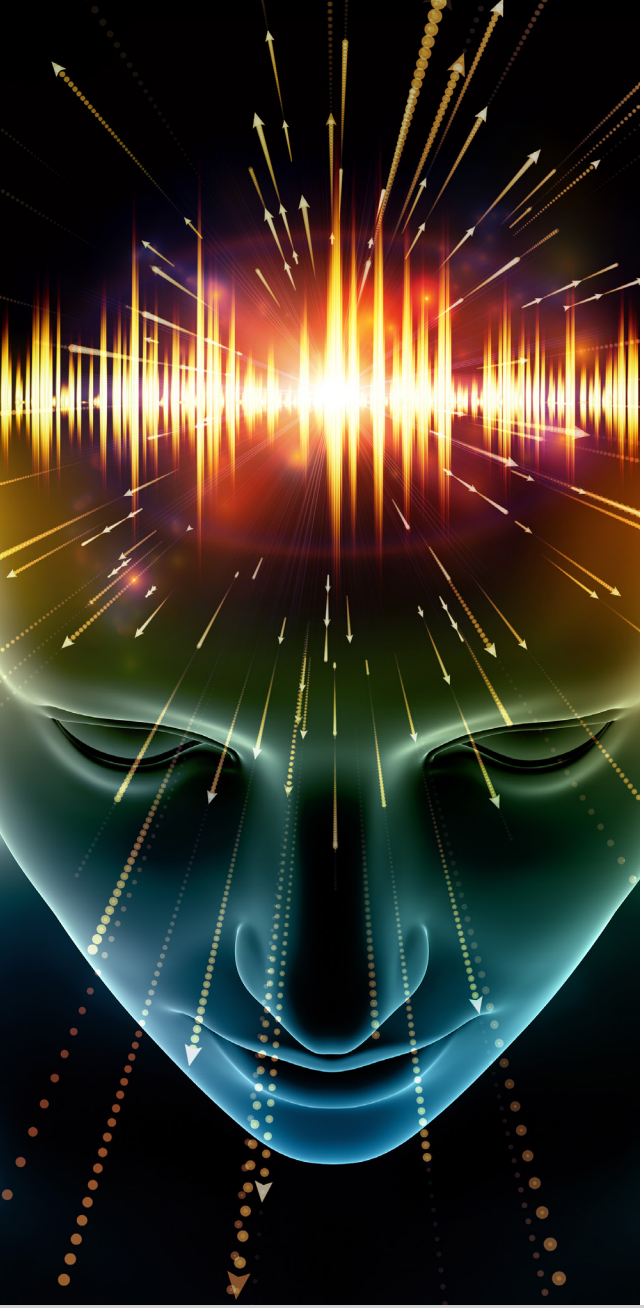
Challenges:

- The building industry has been reluctant in adopting new technologies such as BIM, with many planners preferring to stick to established methods [51]
- VR technology has not yet achieved economies of scale, resulting in expensive hardware [52]
- High-quality VR graphics require much more computing power than equivalent graphics on a standard display [52], [47]
- Devices meant for use on construction sites must be robust and this has so far not been a focus of hardware manufacturers
- User experience is still an issue, either due to technical glitches or motion sickness [53], [54]

Impact on the construction industry:

Visualization technologies have the potential to improve the construction industry in a variety of ways. Error rates in the design phase will decrease as architects will more easily identify mistakes. The same is valid for the execution, where AR will increase compliance with the BIM model. On-site, workers will have easier access to the information they need, increasing efficiency. The AR layer can add contextual warnings that will increase worker safety. Last but not least, virtual tours of future buildings will increase buyer satisfaction and help reduce the number of late change requests, thereby reducing delays and budget overruns.





ARTIFICIAL INTELLIGENCE

Increasing Efficiency and Productivity

AI is currently one of the most discussed technology trends. The reason for this is that machine learning, clustering, and image recognition are very flexible methods which provide precise and valuable insights into complex processes [55]. Indeed, they can adapt to their environment and solve tasks that usually require a certain degree of human intelligence. As AI algorithms are increasingly evolving towards mature computational methods, more and more industries are adopting them. Several of these industries, such as manufacturing and transportation are adjacent to the construction industry or at least share similar processes [9]. Following their example, the construction industry will have to adopt these technologies and will, as a consequence, experience considerable relief of its processes with cost and time overruns representing two major shortcomings in daily procedures [56]. By having intelligent software tackling the complexity of construction projects, procedures can be simplified, time schedules optimized, and multiple tasks automated [9]. Nonetheless, the adoption of AI in the near future is expected to happen only at a very slow pace [57]. Yet, increased labor shortage, low productivity [58], and the rising competition from new AI-powered market entrants will steer the industry in this new direction [9].

Facts:

- In Germany, labor-productivity in construction increased only by an average of 4.1% over the past decade, compared to a growth of 11% for the total German economy and 34.1% in the case of German manufacturing [3]
- The increases in productivity could reach up to 1.6tn USD when compared to other industries already employing applying these technologies [56]
- It is estimated that about 20 construction firms in the US focus on data science to increase the productivity of their building process [58]
- Globally, large projects usually finish 20% beyond schedule and exceed their budget by up to 80% [1]

Key Drivers:

- The pharmaceutical industry has been investing in predictive AI solutions, mainly to forecast medical trial outcomes. These applications can be directly applied to the construction industry to forecast project risks [9]
- Breakthrough image recognition methods developed in healthcare to support the diagnosis of illnesses could be applied to drone imagery and 3D-generated models to assess issues with quality control [9]
- For the retail supply, AI was able to reduce manufacturing downtime, reduce oversupply, and increase predictability of shipments [9]

Challenges:

- Digitalization is key to provide data for AI applications. However, traditional players in the construction industry have a very conservative perspective, especially towards digital technologies [59]
- In order to train AI algorithms, large amounts of data (in this case projects) are needed. This reduces the benefit for smaller companies, especially in the short term [9]
- Restrictions on data sharing and data ownership will increase the challenge of data collection [9]
- Simplifying and integrating the planning process in construction is very difficult due to its complexity [59]

Impact on the construction industry:

AI algorithms will play an important role in improving efficiency in the construction industry. By optimizing time schedules and transportation routes, whether it is on- or off-site, it will be possible to improve the retail supply chain and cut time and cost overruns essentially [9]. Combining BIM models with image recognition will automate the time-consuming job of identifying and labeling construction issues based on pictures [57]. As a result, the builder-owner will benefit from higher schedule reliability and lower costs [3].

REMOTE COLLABORATION AND COMMUNICATION

Increasing Number of Software Solutions for Mobile Communication and Collaboration

Over the last 10 years, the market of cloud computing grew rapidly including a significant increase in cloud-based software solutions [60]. With this cloud software, shared data can be accessed from wherever there is an internet connection. Therefore, devices no longer have to be in a specific physical location in order to access data. Additionally, a cloud-based solution often comes with more advantages such as such as real-time collaboration or version control. These features allow multiple parties to work on the same file simultaneously without loss of data.
In 2016, long-term evolution (LTE) coverage reached 96 % of all households in Germany [61]. This does not only increase mobile availability but also allows a fast use of cloud-based software solutions from almost everywhere in Germany.
In the future, one application of remote collaboration which will be particularly interesting for the industry is the collaboration in BIM. As BIM is continuously penetrating the market, it is expected that it will gain more relevance in the future especially for the building phase [2]. In that case, a collaboration solution for BIM that allows all relevant stakeholders to work on the same file seamlessly might be of big impact.

Facts:

- Project managers in the German construction industry spend up to 90 % of their time communicating [3]
- Architects, Engineers and construction managers often receive over 100 emails per day only concerning construction defects [57]
- A study from 2016 by Roland Berger shows that BIM is rather used in the planning phase than in the building phase [2]
- Awareness for cloud solution increases: While in 2016 only 62 % of construction companies in the US stated that they already use cloud-based solutions or are planning to do so in the future, the number increased within the same group of companies to 85 % in 2017 [62]

Key Drivers:

- Construction projects constantly increase in complexity due to heavier regulations and more stakeholders [63]
- The demand for mobile apps to collaborate and communicate between the construction site and office constantly increases [18]
- Many computer-aided design (CAD) players shift their software to the cloud, such as Autodesk's integration into Dropbox [18]
- By 2020, public infrastructure projects are required to use BIM, which further increases the need for suitable collaboration software compatible with BIM [2]

Challenges:

- The construction industry is among the least digitalized industries which results in incomplete digital data. Hence, digitalization has to progress first before remote access to data is implemented [1]
- Construction companies lack in adapting digital devices: In 50 % of the researched companies, less than 40 % of employees own a smartphone [3]
- While German cities usually have 100 % LTE coverage, construction sites in rural areas often have worse coverage [64]

Impact on the construction industry:

Software solutions for remote communication and collaboration potentially will have a large effect on the construction industry. for the following reasons. Communication and collaboration will shift to the digital age which will allow stakeholders to save time and increase ease and efficiency in very simple processes [65]. At the same time, this will enable them to contribute more time to critical meetings and complex tasks. Additionally, working in a cloud increases transparency of every stakeholder's work which increases trust between them, especially between end-customers and construction companies [66]. Hence, the atmosphere in the entire industry will shift to a more trustful industry.

SOCIETAL & ENVIRONMENTAL TRENDS

INFLUENCES ON THE DIGITAL FUTURE OF THE CONSTRUCTION INDUSTRY

Space as a Service
Downsizing Living Space
Increasing Selectivity in Employer Choice
Customization
Green Building
Migration of Labor Force into Local Market

Ibrar Arshad, Kaya Dreesbeimdiek, Benedict Gruber, Simon Höferlin, Mathis Stolz

SOCIETAL & ENVIRONMENTAL TRENDS

Shaping the Digital Future of the Construction Industry

Since humankind began to settle down, the built environment has been created to frame and facilitate human activity. Today, buildings serve more than just as a basic need. Construction nowadays also reflects the social and cultural status of a society including values, lifestyles, and desires of individuals. With people adapting to economic, technological, and social changes, building concepts are also constantly being redefined. Identifying emerging behavior patterns contributes to the development of future-oriented buildings and construction methods. In this report, we describe six trends that are expected to impact the construction industry in two aspects: First, they give an outlook on possible future design and properties of buildings relevant to a broad share of society. Second, they cover the way in which work patterns in construction are likely to change.

One of the key changes in consumer behavior is the shift towards customization. Consumers are increasingly demanding individualized products that reflect their personal aesthetic preferences and meet their individual needs. This development challenges the construction industry with a trade-off: While firms can differentiate themselves by offering unique products, this trend affects the efficiency of construction.

In addition, the demands of a highly mobile and fast-paced generation have led to the emergence of the service economy. Enabled by digitalization, people strive for time-saving solutions in both living and working environments that offer optional services on-demand. These new consumer patterns challenge companies to offer all-in-one solutions that enable an easy and flexible lifestyle.

Sustainability is ubiquitous in almost every aspect of our lives. Pressures to reduce CO2 emissions and a growing public awareness to reduce the ecological footprint foster green building activities. These refer to the design, construction, and operation of buildings, that allows the reduction of negative impacts on the natural environment. New energy efficient materials and systems foster this trend.

For urban environments, new concepts to tackle the high influx of people to cities include a reduction of living space per capita. Central aspects of this trend include the shortage of affordable living space, the singularization of households, and the conscious consumer who is less focused on material possessions. These developments require solutions for small-scale living.

Human factors are critical performance drivers in the construction industry. In addition to the aforementioned consumer patterns, change can be observed in workforce-mindset as well. Paying close attention to changes in employees' expectations is crucial. Currently, the share of millennials and generation Z members with different life perspectives and values is growing in society. Consequently, firms are challenged to attract and retain this highly capable cohort of the future workforce.

The German society faces an increased variety in the cultural background of its members. Migration is the key driver of this development. This increased multiculturalism poses challenges concerning integration and language barriers. It is likely that cultural differences will affect the construction industry as a provider of community space and employer.

SPACE AS A SERVICE

Need for On-Demand Space Drives Customer Expectations

We are moving towards a generation for which it is natural that ownership is not a prerequisite for using something. Moreover, this generation is used to receive services and goods flexibly, on-demand, and with a simple and fast process tailored to their current needs. Increased mobility in both private and professional life leads to a generation that is less settled down than previous generations. As a result, there is a higher demand for flexible living space. Those characteristics especially apply to the "Sinus Milieus" of the "Performers", "Adaptive Navigators", and "Cosmopolitan Avantgarde" [67] which make up to one quarter in society with higher social status and re-orientation regarding their basic values. They desire to have multiple options, accelerated lives, and are pragmatic and explorative [67] but also more stressed [68], [69]. Manifestations of this trend are for instance the growth of Airbnb, for flexible rent contracts or the rise of Co-Working spaces [70] like WeWork, offering flexible workplaces plus add-on services and a vibrant community. In a similar way, WeLive is offering "Co-Living" with flexible serviced apartments including a community life, a gym and other perks [71], [72], [73], [74], [75].

Facts:

- The share of 20 to 29-year-old Germans planning to buy a house decreased from 52% in 2010 to 38% in 2017 [76]
- The worldwide number of coworking spaces has risen from 160 in 2008 to over 18,600 [70] reflecting the demand for fast and flexible, all-in-one solutions
- 68% agreed to the statement "the business model of real estate investors is changing as a result of the move towards 'space as a service'" [77]

Key Drivers:

- Increasing post-materialism can be observed which is described as the "shifting from an overwhelming emphasis on material well-being and physical security toward greater emphasis on the quality of life" [78], [79]
- Digitalization enables on-demand products and services such as online platforms and configurators [80]
- The mobility of people will most likely increase [81] and therefore the need for flexible living space
- Business models shift from ownership to service-oriented models [82]

Challenges:

- Customers' on-demand and high service expectations need to be met by the organization of construction projects
- A requirement will be to offer an all-in-one solution with an attractive design, flexibility and demanded add-on services adapting to the customer's current needs
- Without a holistic perspective, construction companies might miss important data to optimize what customers want, especially when not being vertically integrated and iterative

Impact on the construction industry:

First, the spotted trend changes what customers desire in design aspects of buildings, such as pre-furnished and serviced apartments as well as common areas to foster community life and pre-installed smart-home gadgets. Second, customers transfer their expectations of mainly digital, on-demand products, being, in essence, the seamless, flexible, and fast processes, to the construction industry. The construction industry needs to find ways for making the process of building a house, or more generally, utilizing living space, easier and faster to meet private customer's rising expectations [83].

DOWNSIZING LIVING SPACE

New concepts to reduce living space per capita in urban environments

Living space is being rethought in urban areas. As more and more people start to embrace the benefits of metropolitan life, living space is becoming a scarce and expensive resource [84]. People have started to recognize the need for more efficiency and are willing to trade individual living space for proximity to the city center, lower costs, and availability of housing as well as for reduced energy usage. As a result, the trend of reducing living space per capita frees up capacities to offer house to more people and to cut energy consumption, e.g. by not sealing ground any further [85]. This development gives rise to new concepts such as minimalistic, multifunctional, and shared approaches. These concepts aim to create more compact living space while maintaining a high quality of life [86]. Moreover, they account for changes in demographics and family structures. Higher life expectancy and the tendency of young people to delay traditional life choices, e.g. marriage and having children, creates need for accommodation tailored to individual life situations [84]. Therefore, it is likely that the demand for attractive solutions for small scale living will further increase and affect a great share of society [87].

Facts:

- In 77 German cities, around 1.9m affordable apartments are missing with 1.4m apartments among them referring to one person households under 45 square meters [88]
- In 2050, 80% of Germans are expected to live in urban areas [89]
- Compared to the previous-year period, investments for student housing and micro apartments rose by 224% to 1.6bn EUR in Germany during the first half of 2018 [90]
- Average age at which German women have their first child increased from 24 in the 1970s to 29.6 in 2016 reflecting postponed family formation [91]
- There are currently 762 realized and 254 planned community living projects in Germany [92]

Key Drivers:

- Scarcity of building ground, regulations, and rising construction costs shortens affordable living space in urban areas [93]
- A less resource-intense lifestyle and new business models like the sharing economy allow society to reduce personal possessions [94]
- Environmental awareness makes society consider the energy consumption and waste production associated with living space [95], [96]
- The singularization of households, especially among the elderly, possesses huge potential to reduce living space for an individual [97]

Challenges:

- The individualization of society and greater prosperity lead to higher demands for living quality [98]
- Elderly people show a reduced residential mobility as they tend not to move into smaller housing, even though their life situation changes and the number of household member decreases [99], [97]
- Community and participation in living space can emerge only if the need for individuality and privacy is sufficiently satisfied [86]
- Living space needs to be adaptable for different groups of a society and their current phase of life [84]

Impact on the construction industry:

The shift to smaller living space will change room concepts and hence, the designs of buildings. Due to requirements of reduced, flexible, and shared space, construction may go beyond buildings' mere creation. This has important implications for the industry: Firms may get involved with concepts from interior design such as built-in furniture, and flexible elements like movable walls. Moreover, to keep costs low, modularization and serial construction will become more important. Additionally, quality and design standards will get into focus. Hence, the capability to use innovative materials and shapes is an opportunity for construction firms to differentiate themselves.

INCREASING SELECTIVITY IN EMPLOYER CHOICE

Millennials and Generation Z Members Are Reluctant to Join Old-School Employers

Millennials (born between the early 1980s and mid-1990s) and Generation Z (born between mid-1990s and mid-2000s) will constitute the majority of the global future workforce[100] [101]. These two age groups share many characteristics and are equipped with the skills to drive a company's profitability, productivity, and innovation[100], [102]. However, their expectations from a career are very different from those of earlier generations. In comparison to previous generations, they demand more flexibility in work and demand more work-life balance during their careers [103], [104]. Having room for professional growth, and a sense of purpose, are important considerations for them when evaluating employers [105], [102]. They are very tech savvy and also demand a technology-enabled workplace[106]. Because of such peculiar career expectations, these individuals are gravitating away from choosing the construction industry as their profession because construction work is perceived as less digital, hard, and less innovative [107], [1], [108], [109]. The fact that millennials are the least engaged generation in workplace-meaning that they do not have a strong behavioral and emotional connection to the company and consequently are not reaching their full potential is evidence of their shifting career priorities [102].

Facts:

- Only 20% of the millennials in the US are engaged in their jobs while 60% are open to switching jobs. This is indicative of their dismay with old-school methodologies [102]
- By 2030, millennials are expected to make up 75% of the global workforce while 24% of the workforce in 2020 will be made up by Generation Z [100], [104]
- According to the "Generation Z: Global Citizenship" survey conducted by the Varkey foundation in 20 countries, 94% of the surveyed cite physical and emotional health to be crucial for happiness [110]
- Expenditure on Technology accounts for less than 1% of the revenues in the construction industry [1]

Key Drivers:

- Both Millennials and Generation Z want healthy working conditions and safety. However, construction is perceived as stressful and tiring [111], [101]
- Flexibility in work timings is an important consideration for these generations [112], [113], [114]
- Both the Millennials and Generation Z have a need to contribute with their new ideas, collaborate and drive innovation [100], [106]
- Millennials tend to pursue employers that have a vision and offer purpose, challenging work, and opportunities for professional growth [100], [102]

Challenges:

- The on-site work in construction is perceived as hard physical work. Consequently, the easy-lifestyle oriented Generation Z is less willing to adopt construction as a profession [108], [109]
- Digitalization has not yet found its way into the construction industry which is still perceived as mainly manual work [1]
- Construction is a rigid business where existing best practices are followed and hence, there is less room for innovation and new ideas [107]

Impact on the construction industry:

The construction industry has been suffering from skilled-labor shortage [108]. To overcome this problem, it should adapt its work practices to the demands of millennials and generation Z. For example, technology is a big "pull factor" for employees from these generations, but digitalization processes in this industry have been slow [1]. To attract these highly-skilled members of the future workforce, construction firms should adopt idea sharing and collaboration, offer safe as well as flexible working conditions, and should innovate construction processes with technology. In possessing these characteristics, the industry may benefit from the extraordinary work drive of millennials and the Generation Z [100], [101].

CUSTOMIZATION

From Product Standardization to Customer-Driven Models of Mass Customization

The residential building industry is increasingly under pressure to increase output and make new-build housing more attractive to consumers. Mass customization and the use of standardized modules have the potential for meeting both objectives [115]. Recent social and cultural developments challenge the housing industry reflecting a divergence between customer expectations and building design. Whereas consumer demands tend to be heterogeneous, physical buildings are still largely homogenous [116]. As a result of the complexities involved in the estimation, production, delivery, and management processes, most homebuyers choose from a limited number of standard products offered by large production builders. Alternatively, they pay a significant price premium for a customized building realized by a smaller custom builder. As customization options drive consumer satisfaction for their industrialized homes, the tradeoff between production efficiency and great customer satisfaction ratings becomes apparent [117]. Successful adaptations of mass customizations in the building industry can be found in the Japanese prefabrication industry, which operates rather like a production industry than a construction industry and combines automation, products, and services into their business models [118].

Facts:

- The house price index in Germany increased by 11% from 2015 to 2017 [119]
- The share of house owners among the total population of Germany decreased from 53.2% to 51.7% between 2010 and 2016 [119]
- The average purchase value of one square meter of developed building land in residential areas increased by 21% in Germany between 2010 and 2016 [120]

Key Drivers:

- Inaccurate planning and changing requirements are the most commonly observed problems of the German construction industry, making standardization a common driver of simplicity [121]
- A shift towards individualized consumption is widely considered important in several industries, including products, services, and solutions [122]
- Homebuyers are increasingly demanding houses that reflect their personal aesthetic preferences and homes that are individually configured according to their needs [117]

Challenges:

- Deviation from the efficiency of product standardization or selection among products with a standard design comes with increased costs [122]
- Improving the efficiency of housebuilding is essential to meet the challenge of current and anticipated housing needs [123]
- A broad adaptation of mass customization requires methods to facilitate consumer participation to better reflect their expectations regarding the design of buildings [122]

Impact on the construction industry:

The joint importance of product differentiation and economies of scale are challenged by the processes of personalization. National companies might be forced to adjust their differentiation strategies to compete with the flexibilities of local contractors. On the other hand, local contractors might need to adapt production and service innovations introduced by national companies [124]. Modular construction could be introduced as a method of construction which increases the effectiveness and efficiency of the buildings by combining conventional construction techniques with modern mass production models. This could mean that a major portion of the construction work is shifted to high-tech, weather-independent factories [125].

GREEN BUILDING

Sustainable Design and the Application of a Building Lifecycle Perspective

In Europe, buildings account for around 40% of primary energy consumption and therefore significantly contribute to greenhouse gas emissions [126]. Consequently, a good understanding of the nature and structure of energy use in buildings is crucial for establishing adequate future energy and climate change policies [127]. Green building applies a whole life cycle perspective during the design process and considers siting, energy efficiency, materials efficiency, and water efficiency as key elements [128]. Measures and methods of building green include energy management systems for heating, ventilation, and air conditioning (HVAC) optimization, passive building design, and the use of sustainable building materials [129], [130]. Ideally, a sustainable building should bring added value to the owners, investors, and project developers as well as for the users of the property. This value includes energy savings and related cost reductions over the lifecycle of the building, as well as a higher perceived quality of living. But high direct investment costs and a lack of information on energy-efficient solutions at all levels of the value creation chain are obstacles to overcome.

Facts:

- Currently, there are three accepted certificate systems in Germany (DGNB, LEED, BREEAM) with the public German Sustainable Building Council (DGNB) having a market share of over 60% [131]
- Investment in Green Buildings in Germany increased more than tenfold from 600m EUR in 2008 to 7.4bn EUR in 2016 [131]
- In 2017, there were 830 buildings certified as sustainable in Germany compared to 4,206 in UK and 1,397 in France [130]
- About 50% of certified buildings in Germany are office buildings [131]
- In 2017, the KfW committed over 14bn EUR in funding to energy-efficient construction and renovation [132]

Key Drivers:

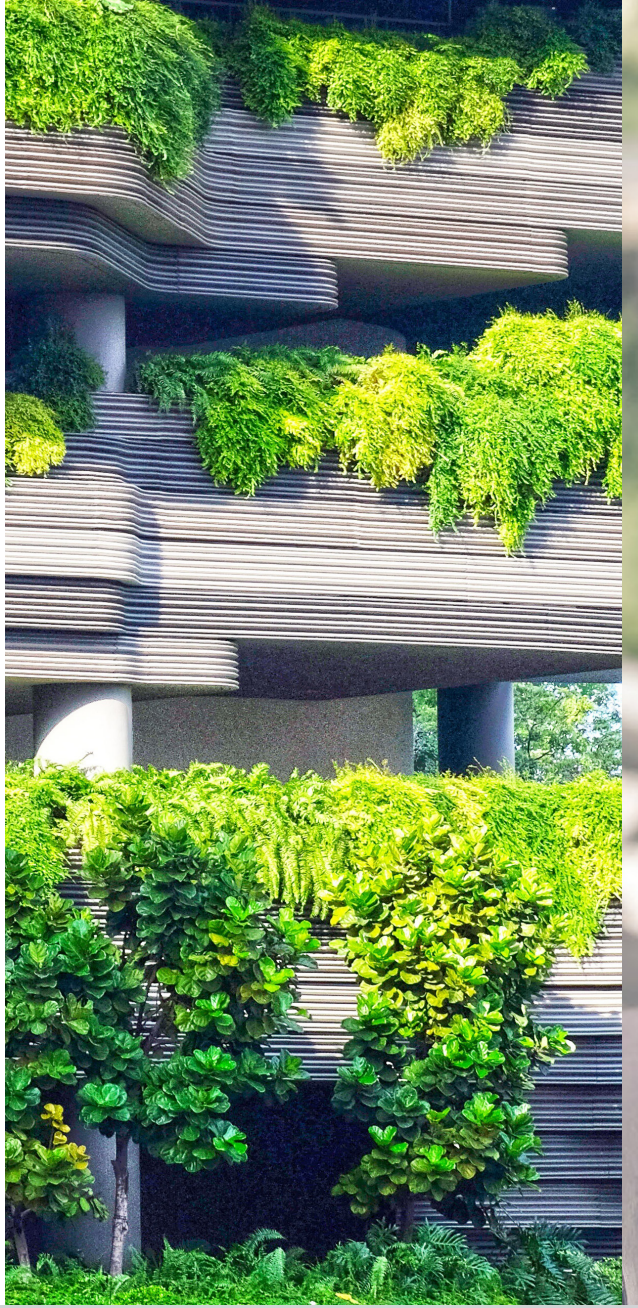
- Public awareness regarding the importance of sustainability drives investment in green building projects [130]
- Better energy efficiency resulting in cost savings might yield higher financial returns on buildings [133]
- Realizable sustainability premiums in rent prices drive profitability of projects [130]
- Green building materials, mechanical systems, and furnishings have become more widely available, and their prices have dropped considerably, decreasing direct capital costs [129]
- Increased productivity in green office buildings is an important aspect of the overall business case to be made for green building [129], [134], [130]

Challenges:

- Because of the higher direct capital costs of green buildings affordability is a key challenge [135]
- The effects of green buildings on rents and prices are difficult to calculate, owing to the heterogeneity of building types and the lack of long-term experience [136]
- Environmental regulations are important triggers for green buildings but strongly vary between markets [130]
- The perception that green building is only for high-end projects with high investment volumes keeps smaller projects from being established green [130]
- The use of a rating system is too costly or time intensive, suggesting the need for better tools and simpler approaches [130]

Impact on the construction industry:

The increasing public demand for sustainable solutions already drives the construction industry to establish green buildings. While big construction companies and sustainable real estate funds might have the financial resources to pioneer green projects, smaller players in the value chain of the construction industry need to invest in developing sustainable solutions. Further, intense collaboration and interdisciplinary project teams are crucial to a successful planning and design process [129]. As the green building trend progresses, it is also important to consider its value depreciating impact on normal buildings. To mitigate this development, building owners should invest in green renovations and recycling techniques [129], [133].



MIGRATION OF LABOR FORCE INTO LOCAL MARKET

Language and Cultural Barriers in the Working Place

The effect of language on the integration of migrants is a commonly discussed topic in politics throughout the world. Germany has a long tradition of working migration leading back to the "Gastarbeiter" agreements back in the 1950s and 1960s, which in part still affect German demographics[137]. However, Schengen agreement and the European migrant crisis have resulted in new developments within the German labor market. The ladder is referred to as the largest source of new labor in the non-academic sector and therefore a promising opportunity for the German construction industry. As both refugees and EU citizens, who seek to work in Germany often immigrated as adults, some parts of work-related skill sets, such as language, might not be developed fully. Construction companies would then have to focus on their employees' further training.

Facts:

- 8% of refugees in Germany are functionally analphabetic [138]
- Roughly a quarter of refugees have good knowledge of German language after their third year living in Germany [138]
- 20% of refugees applying for recognition of their training need help during the application process but do not get proper assistance [138]
- In 2013, 29.2% of employees in the construction industry in Baden-Württemberg had a migration background[139]. Meanwhile, a quarter is reported on federal level [140]
- The proportion of entrepreneurs having a migration background has more than doubled since 2003, now being at 40% (100000 in total) in 2016 [141]

Key Drivers:

- In July 2018 around 482,000 refugees were registered as seeking work, 182,000 were unemployed [142]
- Most forecasts project a population increase in Germany of more than 4m until 2030 through migration [143]
- Climate change is likely to enforce migration towards Europe and could lead up to 1m of the incoming population [144]

Challenges:

- Refugees in Germany are drivers in regard to their native languages, the largest part being Arabic with only 42% [138]
- Only 51% of previous training in their respective professions get fully approved by authorities [145]
- Cultural barriers, such as acceptance of gender equality at the workplace can result in a need for education measures [146]

Impact on the construction industry:

As even after a few years of living or working in Germany - most migrants are not proficient in the German language [145]- special education programs must be considered. Existing language training programs offered by public authorities are available to most employees with migration background. The use of technology can help cover some parts of the language gaps. This can be observed in the health care and insurance industry [147]. Also, especially in the construction industry not only employees but also subcontractors and contesters will be affected by a diversification of native languages and cultural background.

LEGAL & POLITICAL TRENDS

INFLUENCES ON THE DIGITAL FUTURE OF THE CONSTRUCTION INDUSTRY

Citizen Empowerment
Promotion of BIM-Usage
Standardized Waste Management Regulations
Increasing Energy Efficiency Regulations
Smart Contracts
Data Regulations
Recovering Government Infrastructure Spending

Denitsa Angelova, Shiv Contractor, Joana Haase, Marissa Rimmele, Christian Spier

LEGAL & POLITICAL TRENDS

Shaping the Digital Future of the Construction Industry

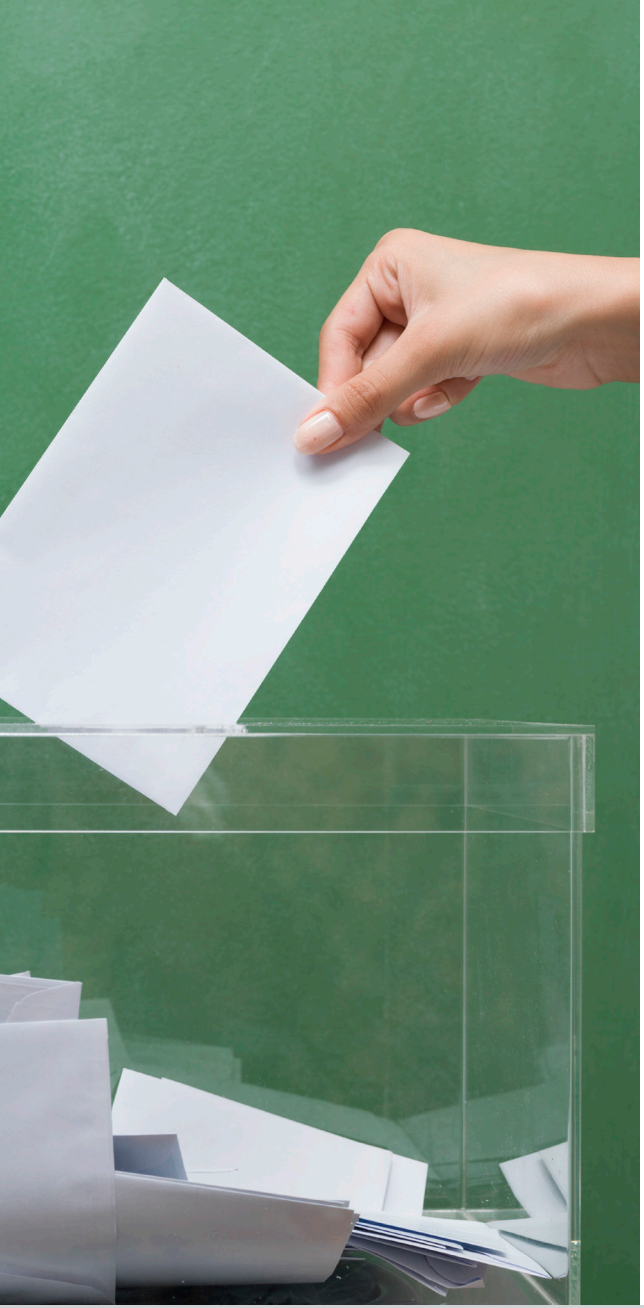
The construction industry has always relied on guidelines, standards, and incentives adjudicated by the government. Laws and ordinances constantly influence the building process, right from planning and construction to demolition and recycling, existing on various levels like EU, federal, state, and municipality level. The EU issues directives that need to be implemented as laws by European countries within a certain time frame. To foster these laws, the German government may issue additional ordinances that describe the specifications of how a law should be implemented in a specific region, for certain goods, or in a specific industry. By identifying governmental policies, regulations, and incentives, the following illustrates future trends owing to political and legal factors, concerning the construction industry. The past few decades have witnessed an increase in the environmental awareness and international commitments for ensuring a greener future on an individual as well as institutional level. As a result, the German government has ratified several regulations regarding increasing energy efficiency and reducing the carbon footprint of the construction industry.

Another environmental trend goes towards more standardized waste management regulations. In Germany, there still exists a multitude of different ordinances on municipality and state level. New laws are planned to harmonize those regulations, creating an up-to-date legal basis, which is unified for all German states. In addition, increasingly empowered citizens are driving environmentally conscious policies. Through a growing number of referendums, public participation in the decision-making process has been on the rise. Citizens have the power to influence or even put an end to large construction projects. In recent years, a lack of transparency and information to the public has led to the failure of many housing and infrastructure projects.
During the last decade, a discrepancy between government and municipality spending has led to a large number of underutilized government funds. This has resulted in a delay of many critical infrastructure initiatives, i.e. the expansion of broadband and electricity grids. Now, a strengthened financial situation of German municipalities indicates an increased demand for public construction projects.

With a high demand for construction projects, pressure for innovation in the industry is low. This has led to the German construction industry being slower in the adoption of technological advances than most other industries. The current government has often tried to encourage digitalization, especially through the use of BIM. Task forces are being dedicated to the promotion of BIM and governmental regulations are being passed requiring companies to use BIM for infrastructure projects.

Even though the construction industry is slow in adapting to digitalization, technologies promise faster execution and less risk in planning and safety. However, underlying data privacy regulations are necessary to foster new innovations. Growing collaboration opens up new questions regarding intellectual property, data privacy, and security of data flow.

Another technology that might have an impact on the building process is “Smart Contracts”. These self-executing protocols will make the current process more transparent and reliable. Therefore, policymakers should consider how to cope with legal impediments and encourage the adoption of intelligent contracting.



CITIZEN EMPOWERMENT

Rising Willingness and Opportunities for Citizens to Participate in the Public Decision-Making Process

In the past decade, large-scale infrastructure projects have been increasingly present in the public eye. People protesting "Stuttgart 21" and the construction of a third runway at the Munich airport have been highly publicized. Oftentimes, high costs or environmental consequences of a project lead to public outrage, which may result in public referendums. If a referendum is successful, it can paralyze construction projects and at times even stop an entire project. Even though "Stuttgart 21" was continued, protests led to a delay of almost a year [148]. In Munich, a referendum prevented an additional runway for the airport [149].

In addition, the public influence on city planning is increasing. In 2004, a referendum in Munich decided that no building in the city is allowed to be higher than 100 m. Ten years later, a referendum regarding the development of the abandoned airport Tempelhof declined the construction of residential housing on in the peripheral area [150]. A lack of transparency and information of the public has led to the failure of many projects. With an increasing willingness of the public to engage in the decision-making process, the influence of public opinion on construction processes is increasing and needs to be considered during planning and construction [151].

Facts:

- In Germany municipal petitions for a referendum and citizens' decisions have increased since the 1990s from less than 50 procedures a year to around 300 procedures in 2015 [151]
- From 1995 to 2015 there have been 2,727 referendums in Bavaria, representing almost 40% of all referendums in Germany during that time period [151]
- In 2014, 67% of German Citizens wanted to participate in the decision-making process [152]
- In 2001, the Aarhus Convention went into effect, providing a right for "access to environmental information" and "public participation in environmental decision-making" [153]

Key Drivers:

- For the election in 2018, all parties in the Bavarian Parliament (CSU, CDU, the Green Party and the Free Voters Party) state plans to include citizens in important decisions, with an emphasis on decisions regarding development of cities and residential constructions [154], [155], [156], [157]
- Regulations for referendums are becoming increasingly citizen-friendly with less exclusion of topics from referenda, lowering the number of required signatures for a referendum and prolonging of the deadlines for the collection of signatures [151]
- Results of referenda are greatly accepted by the public and enjoy a high legitimacy [151]
- The willingness of the public to participate in the political decision-making process is increasing [151]

Challenges:

- Citizens often lack interest for projects as long as they are not impacted directly and harbor a "not in my backyard"-mentality [158]
- Large-scale infrastructure projects are often not accepted by the public [158]
- Growing complexity of projects makes it more difficult for citizens to be informed [159]
- 29% of referenda are declared as inadmissible, often because of restrictive case law, lack of experience by initiators as well as a high number of required signatures [151]
- Participation-paradox leads to increasing public interest and engagement with increasing progress in the construction progress with a decreasing possibility of participation [158]

Impact on the construction industry:

Especially in local projects, the influence of public opinion will grow. To prevent citizens' outrage about a project, the public will have to be informed at an early stage. Construction projects will need to increase available information to the public but will also have to bring that information to the public. Transparency and continuous involvement of the public might help contain protests and decrease the feeling of arbitrary decision-making by politicians [158]. If communities do not feel involved in the construction process, citizens` initiatives can slow down or stop a project [151].

PROMOTION OF BIM-USAGE

Governmental Measures for Increased Utilization of BIM

The German construction industry has been relatively slow in adapting to digitalization. Compared to other EU countries, Germany is far behind, especially, regarding the implementation of BIM [19]. In a study conducted by the Fraunhofer-Institute, almost one-fifth of people working in the German construction industry did not know the planning method BIM, with only 14% of respondents working with BIM for more than a year. When planners were questioned about their usage of BIM, only 40% of the respondents said that they use BIM more or less frequently [51].

England is one of Europe's leaders in BIM implementation, having already started a BIM-strategy in 2007. Since 2016 BIM Level 2 is required for all public projects, as well as for the public tender process [160]. This results in only 16% of construction companies in England having never worked with BIM [161]. Currently, Germany is following in the same direction, actively making efforts to foster the standardized usage of BIM.

Facts:

- In 2013, the BMVI published BIM guidelines in an effort to standardize the usage of BIM [162]
- On a European level, a standardization committee is responsible for the standard specifications for the use of BIM, as well as the definition of rules for the handling of the resulting data [163]
- Currently, there are several pilot projects using BIM commissioned by public authorities, i.e. the "Bahnknotenpunkte Bamberg", a railway junction in Bamberg [19]
- The minimization of risk regarding cost overrun and missed deadlines through utilization of BIM is stated as a major goal in the coalition agreement between CSU, CDU and SPD (2017-2021) [164]

Key Drivers:

- A gradual scheme by the BMVI: Application of BIM Level I is required for all new projects commissioned by the BMVI starting 2020 [19]
- Stagnation in productivity and efficiency in the construction industry [165]
- Slow adoption of the construction industry to digitalization [165]
- Increasingly large infrastructure projects require reliable planning methods [165]
- Need for early detection of mistakes on construction sites and a decrease of risk in the construction process [166]

Challenges:

- The relationship between construction companies and subcontractors is highly nontransparent [19]
- Slow adaptation of innovative technologies by the construction companies [165]
- Low technology affinity of the construction industry as well as a lack of training regarding modern technology [165]
- High fragmentation of the German construction industry and the resulting high number of small- and medium-sized construction companies make investments in BIM difficult [19]
- A low number of pilot projects involving small or medium companies increases the difficulty to gain experience with BIM [19]

Impact on the construction industry:

With the introduction of BIM into the construction process, projects will become far more cooperative. For this cooperation to work, projects will have to become more transparent and contracts for projects using BIM should include clear provisions for integrated, cooperative and transparent operations [19]. With an increasing need for investment in BIM, smaller companies might get a competitive disadvantage and will need to adapt, i.e. through cooperation with bigger companies [166]. Other results of BIM benefits in construction projects might be an increase in productivity and efficiency, as well as the reduction of planning risks for infrastructure projects [165].

STANDARDIZED WASTE MANAGEMENT REGULATIONS

Unified Waste Disposal Regulations at a Federal Level

The construction sector is one of the most resource intensive economic sectors and generates more than 54% of all waste in Germany [167]. The EU Waste Directive of 2008 paved the way for more unified laws and regulations regarding waste management in the EU countries. Every country needs to ensure that waste is disposed in a hierarchical way, depending on the degree of pollution, and that at least 70% of all construction and demolition waste is recycled by 2020 [168]. Despite those regulations, the increasing amount of waste will be a challenge for the future and landfilling capacities are already saturated in Bavaria. Also, there is no standardized ordinance for all German states. To address this, a new ordinance ("Mantelverordnung") is planned in the near future [169].

Facts:

- The Substance Cycle and Waste Management Act ("Kreislaufwirtschaftsgesetz") is being developed since 1994 and was customized to the requirements of the EU Waste Directive [170]
- In 2014, Germany generated more than 200 million tons of mineral building waste [171]
- Despite the recycling rate of 88% [172], landfills for remaining construction waste are rare and expensive in Bavaria [173]
- Since 2005 the German parliament plans a new ordinance for all German states concerning the usage of recycled material and new limit values for waste disposal [169]

Key Drivers:

- The total amount of construction rubble in Germany increased by 13 % since 2010 and is estimated to further increase in the future [174] [175]
- Due to a landfill shortage in Bavaria, more building rubble will be transported to distant landfills leading to rising transportation costs [175]
- The prices for local waste disposal in Bavaria will go up due to landfill shortage [175]
- As limit value regulations for waste disposal vary from state to state, administrative efforts will be high, if a state cannot dispose of its waste locally but needs to deposit it in a different German state

Challenges:

- If the government implements stricter limit values in the course of new waste management regulations, more waste will be deposited and no longer recycled. This drives waste disposal costs because of the landfill shortage in Bavaria [175].
- Regulation needs to bridge the gap between keeping disposal costs low for construction companies and protecting the environment at the same time [176, p. 2].
- New waste management regulations should pass soon because today's administrative efforts of waste disposal are no longer economically feasible for construction companies. However, the government takes more time than planned to decide on the new regulations.

Impact on the construction industry:

The new waste management regulation ("Mantelverordnung") will entail unified limit values for the disposal of construction waste in all German states. Furthermore, the usage of recycled material will be regulated on a national level [176]. This will lead to less administrative costs. Compared to Bavaria, most German states have stricter limit values for polluted soil. Hence, the "Mantelverordnung" might cause tighter regulations for Bavarian construction companies, when it comes to standardization. Consequently, less waste can be recycled and more waste will be disposed of. This might entail disposal bottlenecks in Bavaria and higher waste disposal costs for Bavarian construction companies [175].

INCREASING ENERGY EFFICIENCY REGULATIONS

Climate Change Awareness and Long-Term Energy Goals are Engendering More Energy Regulations

In the recent spate of urbanization, there has been a rapid rise in the per capita energy consumption, greenhouse gas emission, and waste generation. As a result, climate change and global warming have set the stage for governments and international bodies to issue regulations and incentives to implement strategies, adopt practices, and use equipment that helps curb these phenomena [177]

The current political landscape of Germany resonates with most other nations regarding environmental concerns. Over the past couple of decades, Germany has passed several legislations with regard to decreasing energy consumption (on an industry as well as an individual level), increasing energy efficiency, and incorporating renewable energies into the power grid [178]. Due to the infrastructural changes pursuant to these regulations, the construction industry is either directly or indirectly involved in these small-, medium-, and large-scale projects.

Moreover, there has been a notable surge in the awareness of environmental issues among the general public, investors, and industry personnel. This awareness coupled with positive reinforcements in the form of financial incentives are conducive to a major transformation in the construction industry [179].

Facts:

- The German National Action Plan on Energy Efficiency (2014) entails raising funds and introducing tax incentives for energy efficiency measures [180]
- With the Energy Efficiency Strategy in Buildings, the Government aims to achieve a virtually climate-neutral building stock by 2050 [179]
- The Energy Saving Ordinance (2014) includes benefits for electricity generated and consumed internally [181]
- KfW's 'Energy-efficient Refurbishment' program provides financial support for an energy-efficient renovation of buildings [180]
- The German building sector accounts for 35% of final energy consumption, causing one-third of the total produced greenhouse gases [179]
- In Germany, 64% of today's building stock has been erected without obligation to adhere to any efficiency standards [179]
- Approximately 350,000 - 400,000 flats are being built in Germany every year; increasing at a rate of 0.5% per year [182]

Key Drivers:

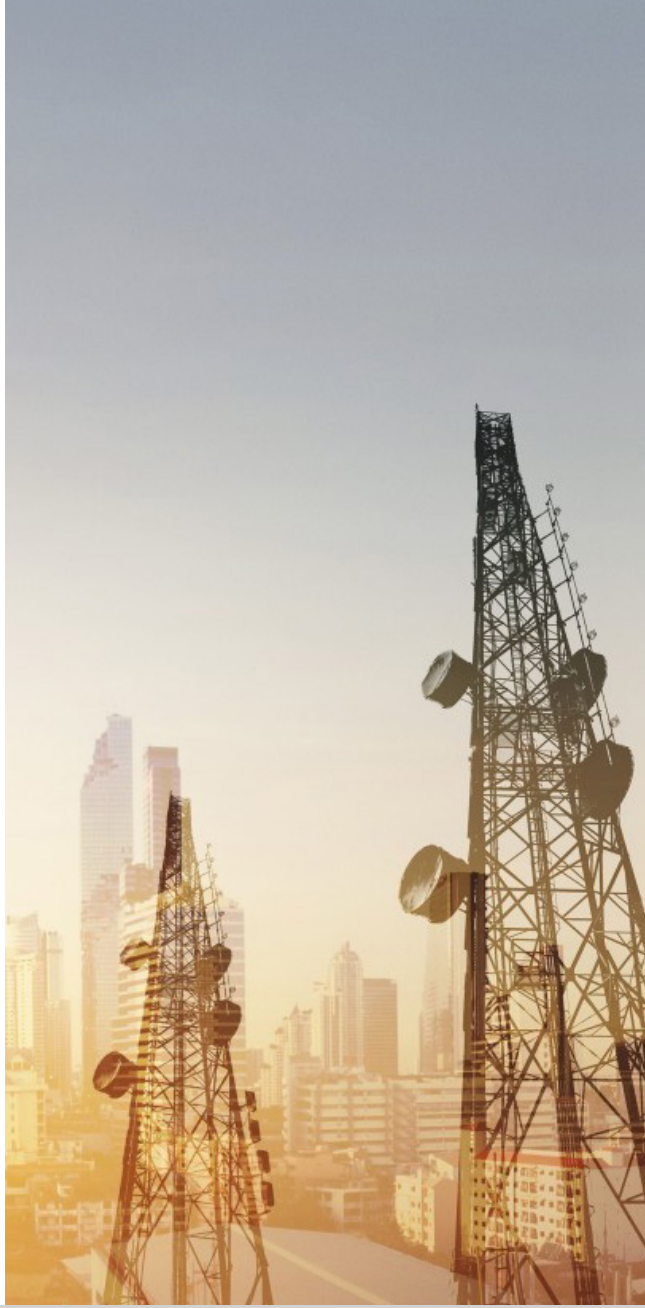
- The energy balance of a large share of residential and non-residential buildings in Germany is not up to the current standards [179]
- Increased awareness regarding energy saving and climate change among individuals, which reflects onto their purchasing behavior and buying patterns
- Energy labeling of products bolster the market penetration for energy-efficient products [183]
- Tenancy laws allow the owner a rent increase option after energy-saving modernization [184]

Challenges:

- Energy-related renovation of buildings will require permissions from all owners and tenants involved [179]
- New infrastructure needs to be developed to achieve higher energy efficiency, e.g. heat grids [185]
- There is a lack of citizen interest to go through the inconveniences and costs encompassing renovation
- It will be difficult to effectively analyze all pre-existing buildings in order to suggest energy-efficient retrofits [186]

Impact on the construction industry:

With increasing energy efficiency regulations coming into play, governmental incentives and tax exemptions will encourage more people to undergo energy efficiency related renovations. Furthermore, an increased transparency in the energy quality and consumption information will lead to a consumer-driven energy market [187]. For instance, initiatives such as the EU label will go a long way into incentivizing manufacturers to develop energy-efficient products [188 17]. A rise in on-site energy consulting and installation at residential properties as well as small and medium-sized enterprises (SMEs) may lead to the inception of a whole new market for energy experts as well as technicians, creating thousands of jobs [179].



SMART CONTRACTS

Revolutionizing Relationships Between Customers, Contractors, and Subcontractors

In the age of digitization, intelligent machines are gradually making their way into the construction industry. Following this trend, law practitioners may soon realize new ways of smart contracting. By definition, a "Smart Contract" [189] is a piece of software which reflects the logic of a legal contract in a sequence of if-then clauses. It continuously monitors if a certain event has happened and automatically executes predetermined actions; e.g. exchange of services [190], [191]. From a legal standpoint, it may be seen as a subject of a mutual declaration of intent between at least two parties [192], where a party could be an organization, a person or machine. Nowadays, the construction industry struggles with a plethora of paperwork and bureaucracy with regard to contract formation and execution. Additionally, it takes inconveniently long time to purchase all the needed materials. Smart contracts seem to be a very promising digital tool for reducing overhead costs and optimizing the process of how business is done in this industry [193].

Facts:

- The introduced GDPR from May 2018 will require companies to disclose all data related to customers or EU-citizens within a fixed time period. Even though data in the blockchain is pseudonymized, every participant is considered a responsible party in terms of data protection [191]
- The company Datarella successfully tested an automated blockchain system for arbitration procedures. The dispute settlement mechanism combines a smart contract library, and blockchain arbitration rules [194]
- First initiatives for using smart contracts in the construction industry were launched in the US, e.g. BuildCoin [195]

Key Drivers:

- Blockchain can be used as an independent trusted and trustworthy instance which guarantees the authenticity of smart contracts in a time and cost-effective way [192]
- Innovation in technology such as IoT or AI and ongoing automation require new types of self-executing, self-enforcing contracts for machine-to-machine communication. Increasing use of smart sensors in combination with big data algorithms provides structured data about occurring events and changes [196]
- SMEs in the construction industry need standardization and process optimization [193]

Challenges:

- Warranty and liability [197]: Machines are not yet considered legal entities in the German law [192]
- The right to be forgotten in the GDPR conflicts with the architecture principle of blockchain where single entries cannot be deleted [190], [191]
- The lack of standardization for implementing smart contracts could result in higher maintenance costs, which will make them less attractive for SMEs [198] Independent certification authorities and assessment institutes are required for verification of integrity and compliance with legal guidelines [193], [197]
- It is still unclear how a smart contract can be concluded in case of debt or not being able to fulfill requirements [197]
- An automated arbitrary instance ("smart judge" [192]) is missing [197]

Impact on the construction industry:

The use of smart contracts could optimize the contract management in SMEs [HEC18]. Since these contracts are fully automated, they may be able to significantly reduce the time for their manual processing as well as transaction fees and costs for intermediaries. Additionally, the scope, type, and size of contract disputes will decrease [199]. Due to the shared transaction history, smart contracts will increase trust through transparency and reliability [190] and will reduce compensation risk. This makes them very suitable for the implementation of trust agreements and insurance policies [192]. Furthermore, marketplaces for smart contracts for SMEs could be developed in the future which will facilitate the adoption of intelligent contracting [193].

DATA REGULATIONS

Novel Technologies and Data Regulations are Pushing the Industry Towards Data Standardization

The construction industry is perceived as one of the slowest moving industries regarding digitalization efforts. However, institutions like the European Union are constantly working on tightening data privacy regulations and enabling data-driven business models, putting a lot of pressure on the construction industry, in particular. For instance, the onset of the General Data Protection Regulation (GDPR) on May 25th, 2018 poses a challenge for many small and medium-sized businesses that struggle when it comes to storing data digitally. Additionally, the implementation of collaborative and cloud-based technologies such as BIM, IoT, or AR is being tested via pilot projects by major players in the industry. Although such technologies promise faster execution, less planning, and safety risks as well as increased collaboration, they also bring up new questions regarding intellectual property, data privacy, and security of data flow. Proposals for a free flow of non-personal data have been accepted within the EU, enabling the usage of connected devices in the workplace. There are several regulations to be pronounced in order to find the right balance between safety, efficiency, and privacy.

Facts:

- EU flagship initiative 'Innovation Union' aiming to encounter obstacles like expensive patenting, slow regulatory changes and skill shortages [200]
- EU proposal for the free flow of non-personal data adopted on Sep 13th, 2017 [200]
- The onset of the GDPR on May 25th, 2018 [201]
- Introduction of BIM as a standard requirement for public infrastructure projects in 2020
- Mostly 'pen and paper' documentation, while a single construction project can generate up to double-digit terabyte data [202]
- Government incentives for technology transfer [203]

Key Drivers:

- Platform technologies such as the 5G communication standard enable data transmission on construction sites in near real-time
- Adoption of BIM software across Europe has proven itself as time- and cost-efficient [204]
- Increasing awareness of data privacy by the end user

Challenges:

- Changing the mindset to store customer information digitally, since data storage is highly manual at the moment
- Intellectual property issues arise in collaborative project design
- Fear of increasing competition due to higher transparency
- No common legal frameworks for innovative technologies
- A chasm between administrative and operational levels

Impact on the construction industry:

Altogether, the adoption of connected devices in the workplace, increasing data privacy regulations, and the rise of BIM will urge the German construction industry to accelerate its digitalization efforts and thereby become competitive when it comes to construction time and costs. Further regulations regarding intellectual property rights, data storage, and transmission will be issued to ensure frictionless collaboration, adequate usage of novel technologies, and further norms and standards to encourage innovation on construction sites.

RECOVERING GOVERNMENT INFRASTRUCTURE SPENDING

Paving the Way for Digitalization of the Construction Industry

Since the implementation of debt brakes in 2009 as a result of the financial crisis, an investment bottleneck has prevailed in Germany leading to tight budgets in municipalities. With municipalities being the largest contributor to public construction investments, their financial situation is a major determinant in the success of implementing government funding programs. Because the funding rate of the Federal Ministry of Transport and Digital Infrastructure (BMVI) for its broadband expansion program is 70%, but municipalities can only afford to cover 55% of public construction spending, available sources of capital are underutilized, and major infrastructure projects are being delayed. While the municipalities have suffered from a severe increase in costs for social benefits, relief programs by the national government and increasing financial returns have strengthened the financial situation of German municipalities and fostered construction investments. Major government campaigns such as the Housing Construction Campaign ("Wohnbauinitiative"), the Energy Transition ("Energiewende") or social housing campaigns are promoting the construction industry economically, socially and environmentally.

Facts:

- Total investment into construction increased by 9.5% between 2008-2015 [205]
- The BMVI increased the funding program for broadband expansion to 4bn EUR in 2015 with a funding rate of 70% [206]
- 72% of all public investments are construction investments having decreased from 85% in the early 1990s [206]
- Negative growth in recent years, reluctance in investments: 2015 (-1.9%), 2016 (+0.1%), further growth expected [207]
- Municipalities have a major impact on public construction; in 2015 they drove 54% of all public construction investments [208]

Key Drivers:

- Investment backlogs from past years have increased the demand for governmental construction projects (schools, sports facilities, administration buildings) [207], [208]
- The collaboration of federal-, state- and municipal governments improved the financial situation of municipalities
- Municipalities have faced a severe increase in costs for social benefits, e.g. youth aid, asylum, social services providers (+56% from 2007 to 2016) [206]
- Further increased fiscal revenue (2016: +3.3%; 2017: +4%) [208]
- Additional government funding programs for weak communities (relief program, municipality aid programs, relief for asylum costs)

Challenges:

- Consistency in implementing already decided government initiatives, caused by potential revision due to change in governing parties
- Economic Policy Uncertainty Index display high figures in the last 8 years [207]
- Increasing planning security proves to be difficult due to a large amount of stakeholders
- Public investments further restricted by measures to cut government debt
- Shortage in public administration staff could delay approvals for public construction projects
- Differences in the financial position of municipalities depending on their state (economically weak/strong regions)

Impact on the construction industry:

Due to restricted budgets, combined with soaring costs for social benefits, German municipalities were not able to fully utilize the resources provided by the German government. This is contributing to the delay of infrastructure projects that are critical enablers for the country's digitization efforts. For instance, out of 7,700km planned for electricity grid expansion across the country, only 850km have been realized, and there are many more examples for Germany's need to catch up with broadband- and electricity grid expansion to eventually reduce the divergence between planned and real costs of construction projects.

ECONOMIC TRENDS

INFLUENCES ON THE DIGITAL FUTURE OF THE CONSTRUCTION INDUSTRY

Deceleration in New Residential Construction
Skilled Labor Scarcity
Increased Cross-Border Activities
Local Market Consolidation
Innovative Market Entries
Productivity Improvement

Kilian Egger, Lisa Neu, Yasaman Rajaee, Kai Siebenrock, Till Wiechmann

ECONOMIC TRENDS

Shaping the Digital Future of the Construction Industry

The global construction industry has shown robust growth over the last decade and seems to have fully overcome the severe effects of the global economic crisis in 2008. Nevertheless, construction faces an era of significant economic changes. The following section deals with the recent economic trends in the European construction sector, focusing on Germany. National macroeconomic indicators were analyzed. Based on that, six industry-specific economic trends were identified.

Firstly, drivers for ongoing growth in the German construction market were investigated. Although governmental spending increased over the last years, new residential projects are the driving force behind rising demand. Despite promising drivers like low unemployment rates, population growth or customer confidence, our findings suggest growth in new residential projects will diminish the coming years. As a result, demand for renovation and modernization projects is likely to expand.

Moreover, the labor market situation in the construction sector suffers from a considerable skill shortage. Certainly, the unattractive industry image is a major factor for scarcity in skill. Aging demographics, as well as the increasing implementation of sophisticated technological innovations, will even aggravate this situation. Continuous training of employees, as well as higher salaries, will, therefore, be critical for successful digitalization and product development within the industry.

Furthermore, the operating area of the construction sector gets more and more international. On the one hand, as demand can hardly be met with current levels of workforce and productivity, German construction companies are collaborating with foreign subcontractors. On the other hand, highly specialized German construction firms are expanding activities beyond country borders. Resulting competition might lower construction prices and increase the importance of international partnerships.

Another strategic response of construction companies on rising demand and productivity pressure is increased merger integration. We identified several tendencies towards local market consolidation through subcontractor integration and movements up the value chain. Increased M&A activities suggest further growth of mid-sized companies and increasing industry margins.

The market landscape, however, will change not only through vertical integration but also through market entries of innovative players. The digitally underdeveloped sector offers a fertile soil for emerging construction technology (ConTech) start-ups. The number of new entrants, as well as the availability of suitable digital solutions, increase along with the awareness of established companies for innovation importance. Besides forecasted productivity improvements, innovative market entries will result in fiercer market competition.

Finally, the impact of expanded digital technology usage on lately stagnating productivity was assessed. Comparing the construction sector to other industries, productivity is estimated to increase up to 30%, contributed mainly by digital technologies [2]. An advanced level of digitalization and resulting productivity increases in return will attract further investments and boost growth.

DECELERATION IN NEW RESIDENTIAL CONSTRUCTION

New Residential Projects are the Key Driver, but Rates are Declining

In recent years, residential construction has been the growth engine for the industry and currently accounts for 61% of all construction investments [209]. The new building business was the major contributor, while renovation projects, which have a higher volume, contributed only marginally to the overall growth [210]. Even in the upcoming years, the residential construction volume is expected to increase due to overall economic strength in Germany, which is accompanied by low unemployment, consumer confidence, and increased disposable income [210]. Urbanization creates a significant housing deficit in urban areas and a need for new residential projects. Population growth due to domestic migration further fuels the demand for housing: the number of private households is expected to increase from 41.3m today to 43.2m in 2035 [211]. German policymakers support the positive development through funding programs like "Baukindergeld" and by setting a low-interest base rate, thereby evoking attractive financing terms. However, research revealed that the growth dynamics could be slowed down. The German Institute for Economy Research (DIW) expects an end of recent years' boom and severely declining growth rates [212].

Facts:

- Housing projects accounted for 61% of all construction investments in Germany in 2015 [209]
- Residential construction projects represent the driving force for growth in the construction industry since 2010 due to overall economic strength with an average year over year rate of 12% [212], [209]
- Growth dynamic in new construction volume is expected to be reduced from +13% in 2017 to +8% in 2018, down to +4% in 2019 [212]

Key Drivers:

- Number of construction permissions has been stagnant since mid-2016 [212]
- In urban areas, purchase prices for housing have grown faster than rent, leading to a reduced rate of return for investments [210]
- Central banks have initiated an end of ultra-low interest policies: The European Central Bank (ECB) has announced to end further bond repurchases programs which will lead to a slight increase in interest rates for housing loans [212]
- The growth of construction prices has increased more than inflation [211]

Challenges:

- End of the boom in residential construction projects leads to reduced growth rates [212], [213]
- Demand differs significantly across geographic regions [214]
- Uncertainty in approval rates of construction projects in the future affected by potential new regulations [212]

Impact on the construction industry:

The research shows a reduced growth outlook for new residential construction projects in the next five years. Instead, new political objectives in climate protection and energy efficiency restorations are anticipated to strengthen the dynamic in the renovation and modernization segment. Companies operating in the residential construction segment should prepare and consider engaging in the renovation business. Further, governmental construction projects are also expected to grow due to the improved financial situation of municipalities and the investment backlog of recent years. With this in mind, construction companies should evaluate to expand their business offerings to governmental construction.

SKILLED LABOR SCARCITY

Upcoming Digitalization and Demographic Change Further Increase Skill Shortage

The construction industry is currently suffering a considerable skill shortage [215]. While demand is steadily increasing and productivity is undergoing sluggish growth, the number of construction-related apprenticeship graduates has declined in Germany over the last decade [159]. An overall low unemployment rate of about, 3% as well as the industry's unattractive image to young workers, aggravate the struggle for construction employers to close the skill-gap [216], [217]. As a result, foreign sub-contractors are hired and their unskilled staff, as well as language barriers, are partly responsible for delays, bricolage, and low productivity in general [217].

Two factors threaten to intensify this skill shortage within the next years: aging demographics and the implementation of digital solutions [159], [218], [219]. Firstly, the increasing proportion of elderly people in the population reduces the availability of workforce as more employees retire than young workers enter the sector. Secondly, upcoming digitalization and evolving innovation pressure increase the demand for skilled workers capable of adapting to evolving technologies [220]. Continuous training of staff and higher incentives for potential employees are therefore crucial factors for SMEs to cope with the skill shortage.

Facts:

- Vacancies for skilled workers in the German construction sector increased by 91% from about 7.500 to 14.000 between 2009 and 2017 and it currently takes on average 160 days to fill a vacancy [215], [219].
- The number of apprenticeships in the European construction sector declined from 14 to 8 per 100 employees within the last two decades and adult participation rates in education and training decreased from 9.4% in 2010 to 8.9% in 2016 [159].
- Digitalization in the construction industry is incentivized to increase (e.g. governmental initiative "planen-bauen 4.0") and technological change shifts skill demands mostly towards high-level skills [220], [221], [222].

Key Drivers:

- German project demand in the construction sector has grown over the last decade with annual revenue increases between 3% and 8% up to 114bn € in 2017 [215].
- The working-age population in Europe has decreased by 4% over the last decade is projected to further decrease from 65% to 63% within the next five years [159], [218], [2].
- The number of young skilled workers diminished due to comparably low wages, safety risks, and unattractive working conditions [217].
- Implementation of digital solutions in the construction industry until 2020 increases the demand for skilled workforce [218], [222].

Challenges:

- Increasing sophistication of technology demands new and broader skill set at all levels of construction companies [218], [223].
- Continuous training of staff is crucial for sustainable digitalization, challenging especially SMEs and sub-contractors with comparably low investment capacity [218].
- The construction industry struggles to overcome unattractive industry image and recruit digital talent [224], [223].

Impact on the construction industry:

The lack of a skilled workforce will have profound effects on the development of the construction industry within the next years. Salaries are expected to rise, as stable revenues increase industry attractiveness and low unemployment rates induce better negotiation power for employees [223]. Moreover, skilled labor scarcity decelerates the implementation of digital solutions because investments in new technologies might not seem profitable when critical human capital for the implementation of digital applications is missing. Small companies tend to face higher entry barriers and are forced to focus on certain niches as they might not have enough investment capabilities for crucial implementation of innovative technologies and employee training [225].

INCREASED CROSS-BORDER ACTIVITIES

Large Construction Enterprises and Highly Specialized Companies Expand to Other Countries

Increasing government spending in Europe and the aforementioned trends of increasing need for residential real estate lead to an overall rising demand for construction projects. Due to labor scarcity and only modest productivity improvements over the past decades, existing companies in the German construction industry can hardly accommodate the rising demand. As a result, cross-border activities increase in both directions: highly specialized construction companies from Germany expand their activities beyond country borders and foreign construction companies enter the German construction market. The former highly local industry faces both increased labor movement and an increase in cross-border projects.

Facts:

- The number of international construction projects in Europe increases. The share of international construction revenue in Germany was already high in 2012 with 8,5% of total construction volume (4th largest in the world) and continues to grow. [226], [227].
- Even though margins in foreign countries are often lower compared to Germany, the number of cross-border deals carried out by German construction companies increases. Large German construction companies account for most of the international deals [228].
- International growth in the EU is mainly driven by large and specialized companies. In 2015, 52% of the construction projects carried out by the 20 biggest players in the market were not in their respective home countries [229].
- Especially companies from EU countries with comparatively slow growth in their home market (Spain, Portugal etc.) begin to build capacities for construction abroad. Spain for example together with the US leads with the highest % of construction revenue coming from projects abroad with 14,3 % in 2012 [230] [226], [227].

Key Drivers:

- After years of budget cuts after the financial crisis in 2008, government spending and therefore infrastructure and related investments increase in multiple EU countries. Both numbers of projects and total government-related construction revenue are rising. [228]
- The high spread between EU countries in terms of market growth makes cross-border more attractive [228].
- Increased investments in infrastructure in certain EU countries (e.g. Ireland) cannot be fully covered by local providers and attract companies from markets with less demand [232].
- New technologies like prefabrication together with advancements in logistics allow increasing operating radius [233]
- The gap in wages across and tax cuts within EU countries lead to foreign countries taking over construction projects [234].

Challenges:

- The increasing operating radius of some firms, challenges construction companies which are more locally-oriented, since new capacities and skills are needed to keep up with these large, international players.
- Certain types of projects and methods such as prefabrication give some companies big advantages in increasing their operating radius and shortening construction time. Companies which don't adapt to those new methods might face severe price pressure in certain projects.

Impact on the construction industry:

Since the European construction market shows arbitrage possibilities, foreign companies enter the market and large German companies also steadily increase their number of jobs abroad. These new, well-connected cross-border competitors can offer low prices and challenge existing "local" companies, leveraging their local partner networks. On the other hand, specialized German construction companies such as Herrenknecht increase their business activities in foreign markets. To successfully carry out cross-border activities, improved logistics are required since most of the medium-sized construction companies operate within a radius of 50km [235]. Building up partner networks, therefore, becomes a crucial part of doing profitable business abroad.

LOCAL MARKET CONSOLIDATION

Increased Subcontractor Integration and Movements up the Value Chain Change Industry Landscape

While the German construction industry is still highly fragmented, first movements towards a more consolidated market can be observed [236]. After the market power of large construction companies such as Hochtief or Bilfinger began to diminish, mid-sized companies started to grow their business and are now expanding to take other positions along the value chain [237]. This leads to more integration of subcontractors, which have always been very important to mid-sized companies. Their number and importance for the industry have increased multiple years in a row, but this is changing now [237], [219], [238], [239]. More subcontractors are acquired by local medium-sized construction firms and are not fully compensated by new market entrants, which leads to local consolidation of the market.

Facts:

- Number of insolvencies per year in Germany went down significantly from 4,909 in 2001 to only 1,290 in 2017, but no increase in market entries can be observed [238], [241]
- More and more companies begin to integrate subcontractors down the value chain to increase profitability. Subcontractor usage in companies with >500 employees increased steadily from 30% in 1991 to 50% of overall construction value in 2007, but started to decrease again after 2008 due to higher subcontractor cost compared to work in-house [239]
- Other companies also move up the value chain and engage as project planners [228]
- Investments in the German industry are mainly from within Germany, stable foreign investments [237], [219]
- Even though M&A activity is still low compared to other industries, an increase in the number of deals can be measured. M&A deals mainly come from construction firms integrating up- and down the value chain [228], [237]

Key Drivers:

- High demand and promising industry outlooks lead to most companies operating at their full capacity. To further increase earnings, companies must increase their margin, e.g. by integration along the value chain
- Mid-sized construction enterprises try to professionalize and optimize their businesses by controlling bigger parts of the construction process
- With the increase of complexity on construction sites, integrated companies achieve communication and project management efficiency improvements by replacing subcontractors with internal departments or acquired teams.

Challenges:

- Strategic decisions are needed for mid-sized construction companies on what kind of integrations to focus: full vertical integration in a certain type of construction segment or moving towards a more planning-oriented project management company which coordinates others and offers in-house building capacity for certain types of projects
- Overhead and therefore payroll risk increases when integrating subcontractors down the value chain
- When moving up the value chain, organizational capacity building needs to be managed. Lack of skilled workforce increases due to changing demand for planning skill

Impact on the construction industry:

The integration of subcontractors leads to further growth of mid-sized companies and increased industry margins [242]. Fuelled by this new development, the complexity of operating a construction business in a profitable way increased with more projects managed end-to-end by single companies. This could lead to adverse selection: Good subcontractors are increasingly organized in partner networks or integrated into larger companies; “leftover” companies underperform and subcontractor quality decreases. The elimination of management layers, as well as reduction of coordination effort, allows growing businesses to increase price pressure, which could force smaller companies out of the market.

INNOVATIVE MARKET ENTRIES

Favourable Market Conditions and Innovation Potential Lure Disruptive Entrants

Market entries and investments in construction technology start-ups grow due to overall favorable economic conditions and digitalization potential in the construction industry. Founders and investors have realized that construction lags behind in productivity compared to other industries and that sector could benefit substantially from new technologies. Contributing about 10% to the national GDP with increasing revenue forecasts and stable industry development, the European construction sector offers a promising platform for disruptive entrants [238].

Even though start-ups still struggle with convincing old-established SMEs of their products and services, they are breaking through with mainly collaboration software, offsite construction solutions, project management tools, as well as mobile and cloud integrations [244]. More mature markets like the United States or Japan act as forerunners with role model companies like off-site constructor Katerra or project management software provider Procore [219], [216], [244]. As in other industries, construction is expected to gain significant productivity increases through digital market entrants in Europe.

Facts:

- Less than 6% of German construction companies make full use of digital planning tools [245].
- Global construction start-up and venture capital activity have been increasing from 3 closed deals and a funding amount of about 17m € in 2009 to 119 closed deals and a funding amount of about 1bn € in 2018 [244].
- Networking events like the introduction of the "Tech in Construction" fair in Germany in 2018 evolve and bring start-ups and construction companies together [246].
- Market entry and increased number of industry collaborations of start-ups that offer project management and documentation software in Germany [247], [235].

Key Drivers:

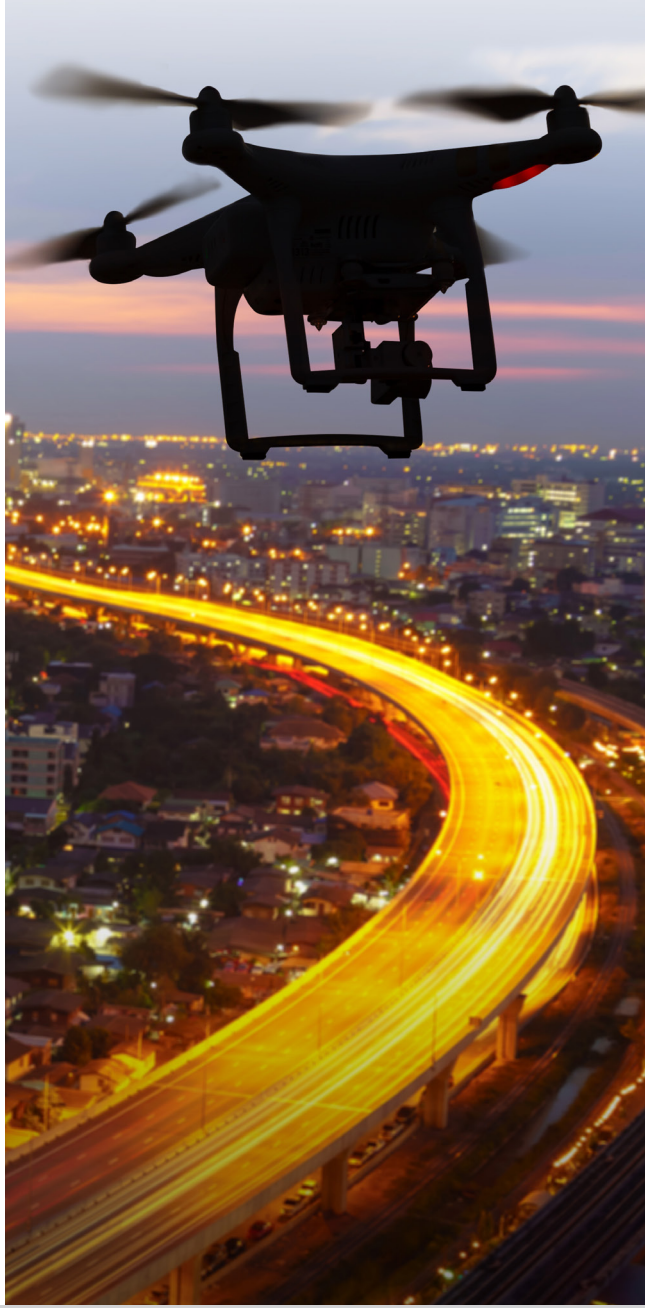
- Economic stability, as well as favorable financial conditions and forecasts for the construction industry, are expected [221], [216].
- Digital solutions have huge potential to increase productivity and margins within the construction industry [219].
- R&D expenses, as well as innovation partnerships, increase within the German construction industry [248], [249].

Challenges:

- Construction companies need to open up for collaboration with start-ups and increase R&D expenditures or partnerships to keep on track [245].
- Risk of disinvestment in unsuitable or short-lived digital solutions [2].
- Entrants need to offer standardized and compatible applications due to high interdependencies between multiple stakeholders in the construction industry [159].
- Work on construction sites is not ready for implementation of digital solutions, especially because of skill shortage [159]

Impact on the construction industry:

Innovative players entering the industry will substantially influence the German construction market. Productivity is generally expected to increase by 10% - 30% through the integration of construction technology and related start-ups [3]. This will allow to meet more of the future demand and augment industry revenues [244]. However, higher revenues will lure new entrants to the market and new technology standards might challenge small construction companies to invest or get forced out of the market.



PRODUCTIVITY IMPROVEMENT

Increased Use of Digital Technologies Drives Productivity

In the past ten years, productivity in the German construction industry has increased by only 4.1%, whereas the productivity development of the entire German economy was 11% during this period [3]. One reason for this modest improvement is the low utilization of digital technologies. Industries of the manufacturing sector, for instance, take more advantage of the opportunities through digitalization, for instance through process optimization and have increased their productivity by 34.1% on average [3]. Even though new technologies are more readily available and digitalization improvements in the construction sector are expected to lead to higher productivity, construction companies only make little use of them [219]. However, this number is expected to grow. A 2017 McKinsey survey reports that 70% of the respondents plan to implement digital technologies within the next three years [233]. The majority of construction companies have recognized the urgency of digitalization and an increase in the use of technologies is expected [221].

The use of digital tools and technologies allows the reduction of coordination activities, more efficient scheduling, greater flexibility, and time as well as cost savings [221] As technology companies continue to enter the sector, construction firms that choose to be early adopters of their offerings are likely to gain market share as a result of their higher productivity [233], [2].

Facts:

- Digital technologies have enabled strong productivity increases in other branches, such as the manufacturing industry. Through the use of "Industry 4.0" technologies, increases in labor productivity between 15 and 27% were realized [250]
- According to a survey by McKinsey, in 2016 just 44% of construction leaders reported that their organizations had adopted some type of digital technology [233]
- Digital advancements in the construction sector are expected to lead to higher productivity [219], [233]. Potential global productivity improvement from the implementation of best practices is estimated to be between 14% and 15% whereas cost savings are assessed to be between 4% and 6% [233]

Key Drivers:

- Increasingly complex projects and rising demand in terms of volume, cost, and quality require the construction industry to improve its productivity [233]
- Many construction projects suffer from overruns in cost and time due to unexpected cost increases, planning errors, and insufficiently calculated risks [233]
- BIM will be introduced by 2020 as the new standard for transport infrastructure projects and forces companies to participate in the digitalization process [219]
- New technologies are readily available and innovative start-ups push digital solutions into the market [233]

Challenges:

- Construction companies are not prepared to implement digital technologies yet since most of the information required to apply digital technologies along the value chain does not exist in a digitized way yet [235]
- Many companies lack the necessary know-how and skills to use new technologies and systems [221]
- Especially small companies are discouraged from introducing digital technologies by the relatively high upfront investment costs for the implementation of software and training of the workers [221]

Impact on the construction industry:

The use of digital technologies allows for the design of leaner processes, better handling of workforce reductions, optimized planning accuracy, and savings in time and costs [221], [233]. For these reasons, a lack of BIM know-how (or other leading technologies) could become a significant competitive disadvantage in the near future [3]. As a result of productivity improvements, the construction investments are expected to increase. An advanced level of digitization and productivity will make the construction industry more attractive to investors thanks to increasing profitability [221].

BUSINESS MODEL TRENDS

INFLUENCES ON THE DIGITAL FUTURE OF THE CONSTRUCTION INDUSTRY

Prefabrication
Life Cycle Planning
Value Chain Reconfiguration
Emerging Digital Platforms
Cross-Company Collaboration
Flexible Resources

Saad Amin, Eileen Einwächter, Sebastian Erhardt, Marc Klingen, Kai Riemenschneider, Jingchen Wang

BUSINESS MODEL TRENDS

Shaping the Digital Future of the Construction Industry

A business model has two basic components: the company's plans to generate sales revenue and the needed operational factors to reach and maintain profitability. The business models in the construction industry have not changed much in the last few years. The industry has remained resistant to digitalization [10], even as digitalization has revolutionized almost every other industry. Because of the industry's conservative nature, the productivity remained low [251]. Today, the industry faces a myriad of changes caused by various social, economic and technological factors. These changes require the industry to reexamine its business models and present an opportunity to adopt digital practices.

Currently, the industry is very fragmented, with small and medium companies choosing to focus on just one stage while bigger companies focusing on multiple stages of the value chain. One way companies can make use of this fragmentation is by evolving their business models to collaborate with one another on different stages of the value chain. Digital technologies enable platforms and project management tools, which could provide a means of enhanced communication and cooperation, not just among construction companies but also with customers and suppliers. These solutions could potentially make it easier to cooperate even on large projects and to help increase the efficiency of the whole construction process.

Collaboration can be extended to resources as well. To find additional resources for peaks in the production or to boost capacity utilization, many new digital platforms are emerging. They try to match the supply and demand to the mutual satisfaction of the involved parties. Flexible resources play a major role in this context and those resources are not limited to hardware.

Another factor that affects construction business models is how projects are calculated and planned. In the past, many negotiations for construction projects only had the goal of minimizing costs in the construction phase [252]. However, many decisions made in the initial planning phase have heavily influenced the asset's operations and maintenance (O&M) costs. Costs can also be reduced by building more efficiently, which is why many construction companies try to use prefabricated elements, which were produced off-site in advance. Because of this approach mass customization like in the automotive industry can be implemented in the construction industry too.

These are just some of the most profound trends impacting the business models in the construction industry. All these trends force small, medium and large companies in the construction industry to rethink and adapt their business models as well as their position in the value chain.

PREFABRICATION

Shifting from On-Site to Off-Site Construction Enables More Efficient and Scalable Processes

Prefabrication is the practice of producing construction components under factory conditions at off-site locations and manufacturing plants. The components can be either standardized or customized and range from individual components to complete structures. They can be applied to various project types, be it small residential houses or large-scale industrial plants. These structures are then transported to the construction site and eventually assembled to construct buildings [253], [254], [255]. Other terms that have been frequently used to describe prefabrication are preassembly, modularization, system building, and industrialized building [256], [257].
Construction companies around the world have been widely using prefabrication for many years, but current industry trends like the increasing use of BIM and lean construction are renewing the industries view on this practice [256], [255]. US startups like Katerra and FullStack Modular, which use prefabrication and modularization, are on the rise [258]. But also, German companies like Max Bögl are refocusing on modular prefabrication in order to tackle challenges like increasing time pressure under high demand in the industry [259]. The benefits associated with prefabrication include faster on-site assembly, more controlled production environment independent from weather conditions, reduced waste generation, and safer working conditions [10], [260], [254].

Facts:

- The market share of prefabricated buildings in Germany has had an average growth of approx. 2.7% per year since 2005 [2], [261], [262], while the market share for prefabricated one- and two-family houses reached 19,3% in 2017 [261].
- Off-site construction companies like Katerra and Blu Homes are redefining and reviving prefabrication in the US [258]. In 2017, Alphabet ordered 300 apartment units for around $30 million from FactoryOS, a modular housing startup based in California, in order to provide housing for employees [263].
- The Japanese retailer Muji has launched a series of small prefabricated houses called the 'MUJI Hut' in 2017 [264].

Key Drivers:

- The increased adoption of emerging technologies like BIM and 3D-printing enable a more efficient use of prefabrication and OSM practices [265], [266].
- In the face of housing shortages and the need for fast construction of affordable buildings, the German government has identified modular construction as a possible solution in their coalition agreement and uttered its support [245], [267].
- Labor shortages force companies to attract workers by offering more pleasing working conditions off-site [268].

Challenges:

- Design flexibility is reduced and limited to possible module configurations and combinations, while users demand individual solutions [10], [269].
- High initial set-up costs as well as increased transportation costs, which depend on the distance from the factory to the construction site, arise [10], [265].
- Due to past experiences with prefabricated buildings around the 1960s, poor image and quality misconceptions of prefabricated buildings still remain [10], [265], [270].
- The handling of large prefabricated components poses a problem in space-constrained construction sites [10], [268].

Impact on the construction industry:

Prefabrication not only experiences renewed attention from startups entering the market, but also offers potential benefits for diversified medium-sized businesses [2]. The impact on the business model depends highly on the level of modularization, addressed end-user segments, dependency on additional resources, and individual positioning in the building process [269]. Conceivable business models range from component suppliers to providers of turnkey solutions [269]. As initial investments are high, the transition towards prefabrication is more viable for medium and large-scale companies which possibly already own a manufacturing site [268].

LIFE CYCLE PLANNING

Plan/Build for the Whole Life Cycle Instead of Only for Construction

Life cycle costing (LCC) describes the process of considering and modeling the present value of all costs along the life cycle of a project when comparing different alternatives in the design and planning phase [252], [271]. In the past in the construction industry, owners negotiated and contracted construction projects based on minimizing costs solely in the construction phase [252]. However, decisions made in the initial planning phase heavily influence an asset's operations and maintenance (O&M) costs and end of life costs [272]. Often, front-loaded inexpensive changes have a significant impact after the construction phase is finished [10], [252]. Thus, LCC is a means to reduce the total costs of an asset by smart and iterative planning.
In other industries, e.g. manufacturing and IT procurement, LCC and total cost of ownership calculations are standard methodologies [273]. In construction, only large asset managers frequently adopt LCC, as they directly benefit from decreased life cycle costs. For projects outside of the portfolio of these asset managers, owners rather focus on minimizing initial costs as they do not plan ahead [252]. LCC is already standardized in some aspects by International Organization for Standardization (ISO), but is not used as iteratively as with BIM [272].

Facts:

- The present value of O&M and end of life costs of a typical construction project account for 40-80% of the life cycle costs [10].
- When the use of construction asset changes, reconfiguration costs are high and heavily impact life-cycle costs. Thus, achieving adaptability of an asset is one of the key goals of LCC [272].
- In Germany, the economics of public projects need to be calculated. To comply, the maximum construction costs for projects to be economic is calculated and no iterative LCC is used [274].

Key Drivers:

- BIM adoption increases and sets the basis for collaborative LCC calculations as the cost trade-offs can be modeled transparently and efficiently. This applies especially for projects not owned by asset managers who perform LCC already [275], [19].
- Construction companies are increasingly commoditized, which drives competition. LCC is a way to differentiate positively from competition [276].
- Environmental regulations changed the mindset of owners to a life cycle view already, as environmental aspects need to be considered holistically [277], [228].

Challenges:

- Incentives of developer, constructor and asset owner are not aligned as they have different preferences for construction and subsequent life-cycle costs [10].
- Stakeholders of construction and O&M phase rarely collaborate, and the information is mostly shared paper-based [278], [19]. Thus, the building performance is uncommonly assessed along the whole life cycle [279].
- LCC calculations are hardly neutral, unbiased, and comparable, given the impact that different interest rate, inflation rate, and lifespan expectations have [272], [10].

Impact on the construction industry:

LCC completely changes the mindset and customer interactions of construction companies. Without LCC, they have very different incentives compared to the owner as they aim to minimize cost and quality within the set specifications. With LCC, construction companies are able to sell quality and good planning and differentiate from the competition without engaging in a price war. Especially measures that prolong a project's life expectancy have a huge impact.

VALUE CHAIN RECONFIGURATION

Companies Rethink Their Positioning on the Value Chain

In the coming years, one of the crucial questions for individual construction firms as well as the industry as a whole would be which stage of the traditional value chain to cover and which not. The construction industry, especially in Germany, is characterized by a fragmented market, low margins, fierce competition and high pressure on prices [38]. Currently, both generalized companies covering most of the value chain in various segments exist just as well as specialized ones that focus on one specific segment or step of the value chain. However, several major players like Bilfinger attempt to extend their coverage of the value chain, while decreasing own construction activities [280]. Similar trends can be observed outside Germany, e.g. the completely vertically integrated construction startup Katerra has just recently received almost 1bn $ of funding [281]. As SMEs adapt to these changes, previous separate steps of the value chain are merged, while opportunities for further specialization in specific parts of the value chain arise.

Facts:

- Due to the complexity of construction projects and extensive subcontracting practices, especially in Germany, an enormous number of companies is involved in the building process, as for example the €8bn infrastructure project "Stuttgart 21" has over 60 companies involved [282].
- Subcontractors account on average for over 30% of the costs for a construction project and, like suppliers, have a huge market power [283].
- Katerra (startup) and Fluor (incumbent) are examples that outperform other construction companies after successful vertical integration [281], [10].
- Major players in the German construction industry like Hochtief and Bilfinger have acquired several companies during the last years which extended their value chain coverage [2].

Key Drivers:

- An increasing lack of qualified subcontractors forces construction companies to perform tasks on their own [38].
- Digitalization and automation drive vertical integration as the management of complex processes gets easier [284].
- Emerging digital platforms take over tasks of traditional construction companies and force them to specialize [285].
- Varied and sophisticated customer requirements open up opportunities for specialized niche firms [280].

Challenges:

- Vertical integration is difficult to implement successfully and costly to reverse in case of failure [286].
- Previous competitive advantages (e.g. cost leadership in building) might hinder good performance in other integrated areas (e.g. R&D) [287].
- Bureaucratic costs arise in the course of vertical integration, which needs to be counted against the possible efficiency gains [288].
- As companies change their coverage of the value chain, no matter whether integrating or specializing, their current corporate culture will not be as effective anymore [289].

Impact on the construction industry:

While highly specialized construction companies had the highest growth rates and highest EBIT in the past years, several industry trends like digitalization and resource scarcity will most likely favor especially highly vertically integrated, big and generalized companies [2], [38]. The majority of locally operating SMEs in between those poles, which already lag behind regarding growth and EBIT, might be forced to move in either of these directions to survive in an increasingly competitive environment.

EMERGING DIGITAL PLATFORMS

Startups Focus on Platforms for the Construction Industry

The construction industry has historically consisted primarily of constructors, manufacturers, and suppliers with direct sales being the preferred form of contact. New startups using two-sided models are changing this by bringing platforms which connect many stakeholders together [258_2]. The digital solutions for the construction industry include not only e-commerce platforms for materials and finished products but also apps and project management tools with a construction focus [258_2]. Currently, these platforms represent the part of the construction industry where digitalization is having the biggest impact. Platform companies like Alibaba and Amazon are already the world's most valuable companies by market capitalization [291]. Digital economy will account for 25% of the world's entire economy by 2020 and platform business models represent an ever-increasing proportion of this overall total [285].

Facts:

- Funding in North American construction technology startups surged by 318 % to $581.6 million in 2017 compared with $182.7 million in 2013 [292].
- New startups in North America and Europe are mainly focusing on creating platforms which bring the consumer and producer closer. [292].
- The top 15 public platform companies account for 2.6tn USD in market capitalization worldwide [293]

Key Drivers:

- Digital platforms are convenient for the consumer thus creating more demand for platforms than direct sales channels [294], [295].
- Building scalable platforms is cheaper and easier than establishing direct sales channels due to the decreasing cost of information technology [296].
- The producer and craftsmen prefer to concentrate on their craft and have platforms focus on the sales and customer reach aspects [294].

Challenges:

- Platforms lead to reduced profits for the participating companies but increased reach can greatly offset this reduction, therefore, companies need to evaluate whether to participate or not. [295].
- Platforms require a necessary number of users to become feasible for all parties involved thus making them unviable for niche product sellers or service providers [296].
- Construction companies' value creation gets commoditized as they lose their face to the customer, trust is not built with the company but with the platform as a middleman. [297]

Impact on the construction industry:

Using platforms for finished goods or services means a complete deviation from the traditional business model of direct sales and contact with customers. E-commerce platforms give sellers of finished products and other service providers the ability to not only make larger gains in customer attraction and productivity but to compete with large companies which are inherently less likely to change as well.

CROSS-COMPANY COLLABORATION

Globalization, Competition, Risks, and Complexity Force Companies to Collaborate with New Partners

The European and especially the German construction industry have always been very fragmented [10], as most of the companies have between 20 and 49 employees [298]. The trend of an increase in cross-company collaboration is a solution to overcome a future where this scattered landscape will stay the same, or even increase. This makes it necessary for those companies to form an interplay along the construction value chain and throughout a complete project life cycle [10], [298]. Many of them needed to collaborate with each other and to become part of shared agreements in order to coordinate the construction of complex projects and products in uncertain and competitive environments [299]. Since the labor resources have been exhausted to the greatest possible extent in Germany, many companies are forced to collaborate with more domestic and foreign subcontractors to find the necessary resources [300], [209].
But even in the face of the ongoing digital transformation, the construction industry has been very hesitant in implementing the latest software and new processes focusing on collaboration and project management [10].

Facts:

- The percentage of production works of subcontractor has risen by 20 percentage points from 1991(30%) until the financial crisis (50%). In the year 2012, it has fallen back to 38% [209].
- The business relations between a general contractor and his subcontractors are stable and continuous over long time periods [301].
- Partnerships and joint ventures are a common practice to share risks in many industries like the oil extraction and petroleum refining, the aircraft industry or automobile industry) [302].
- Because of access to innovation and technology, response to market, resource efficiency, and client requirements, contractors are very positive about collaboration for projects [303].
- Collaboration with multiple domestic and foreign (sub-) subcontractors is becoming a common practice in the construction industry. The percentage of construction workers domestic passport has risen from 7,7 % (2008) to 11,3 % (2014) [209].

Key Drivers:

- BIM is an easy way of collaborating and sharing information between stakeholders [10]. It encourages closer collaboration among design and construction professionals [300].
- There is a mutual consent on new standards like BIM across the industry. Many of them will be mandatory by law in European countries in the near future [10].
- Cost-intensive initiatives as R&D are difficult for individual companies to master on their own [300].
- The competition on international projects against big companies is only feasible for smaller companies if they work together hand in hand [282], [300].
- Construction projects are getting bigger and more complex. Regulations were identified as the most important driver of increasing complexity [251].

Challenges:

- Because of multiple subcontractors from different countries, there will be more language barriers on the construction site.
- Projects with BIM face additional organizational challenges that limit collaboration because companies need to embrace a joint problem-solving approach while collaborating with each other [300].
- There is a cultural difference between companies whenever they are from different stages of the value chain [304].
- Due to additional stakeholders, there is an increase in the length and the costs of stakeholder disputes [251].

Impact on the construction industry:

Many medium and small companies have to work with each other and more and more subcontractors, to be able to deliver projects in the future. The goal is to create a big network of trustworthy partners to rely on. For all these players it is very important to embrace a joint problem-solving culture across companies [300]. If implemented right, these partnerships have a direct influence on the business model regarding the key partners, the key resources and the value proposition.

FLEXIBLE RESOURCES

Sharing Economy Reshapes the Construction Industry

Today, the sharing economy is strong and steadily growing [305]. Unused resources are matched through the internet with the respected demand to the mutual satisfaction of parties involved. New business models rise every day around the world such as Airbnb and Uber. This trend is clearly not limited to B2C markets, but also affects B2B markets. As for the construction industry, it first started in the U.S. with online marketplaces like Getable, which offers to share contractor's idle equipment with other contractors. By extending this initial idea, all types of machinery owners are capable to share underutilized equipment online [305].
It is the same for labor, where hiring halls are being replaced by software platforms (e.g. WORKNOW presented by Colorado Resource Partners), offering standardized pay at a fair wage, supplying workers with skills appropriate to the project, and creating an automated matching system for finding instant jobs.

Facts:

- The U.S. Bureau of Labor Statistics recorded a 4.8% rise in material cost in 2016. In an uncertain market, contractors and suppliers alike are concerned about the rising cost of building materials [306], [307].
- Unscheduled downtime is a big concern for productivity and is mainly caused due to the breakdown of equipment, which is often very expensive to keep as a backup in standby all time [308].
- Many subcontractors and resources strongly indicate that finding qualified workers in the industry remains a major problem.
- There are many successful Sharing Economy business models in other B2B markets, such as GreenTrade in the supplies and raw materials market, and PivotDesk in the hospitality and office space market.

Key Drivers:

- The risk of unused capital is high and low rates of return on that equipment is inevitable [309].
- There is an inverse relationship between the availability of construction jobs and the availability of a skilled workforce in the market [310].
- Timely Delivery ensures compliance with flexible schedules.
- The webstores make cost-effective materials more accessible and protrude the unlimited characteristic in time and space of distance online purchase.
- Staffing platforms increase the level of transparency by avoiding chain leasing [309].

Challenges:

- Due to the high cyclicality and volatility of construction business [10], demands of different companies may positively correlate with one another and hence result in short supply.
- It is hard to ensure that equipment is being properly inspected and maintained [305].
- Potential high labor turnover makes it difficult for companies to keep the knowledge in-house.

Impact on the construction industry:

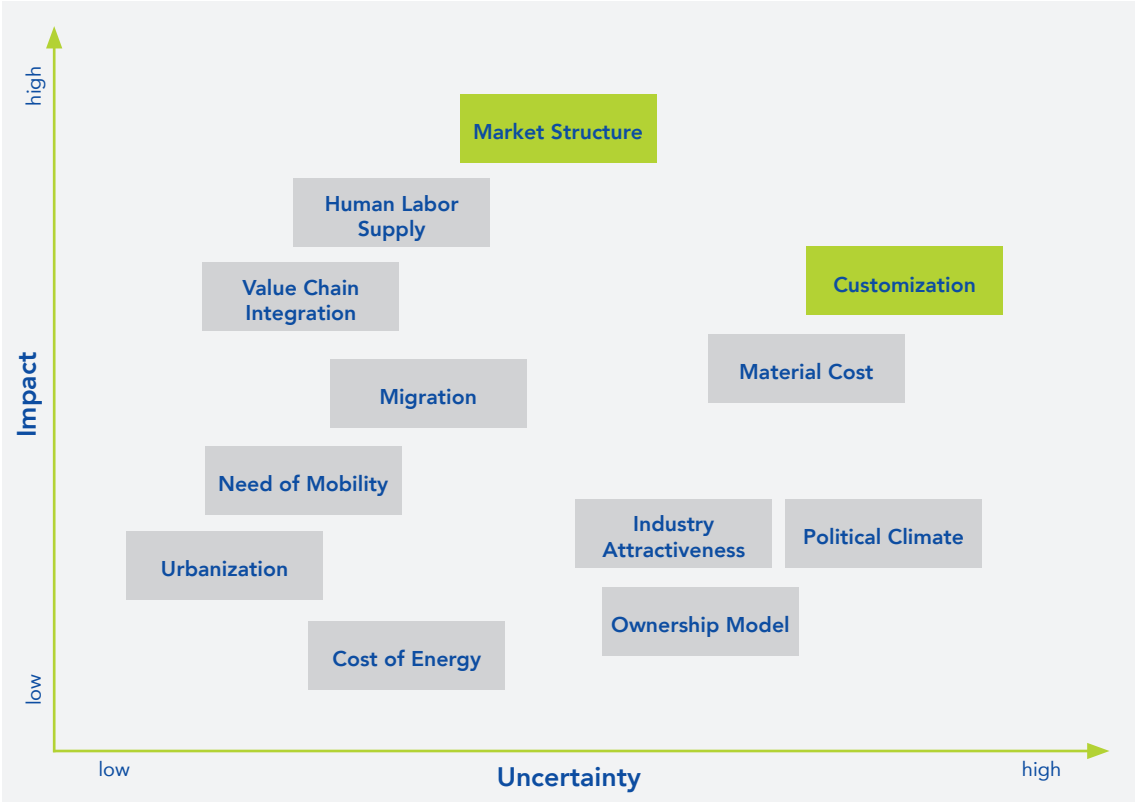
E-commerce and sharing economy greatly increase the availability of construction equipment, labor, and material, allow for fleet optimization, and provide delivery certainty [305]. Thus, they are among the strongest drivers of productivity gains in the construction industry. This will also result in a reduced upfront investment by transforming capital expense to operating expense. Small- and medium-sized construction companies are supposed to be the largest beneficiaries since a greater process-level flexibility is achieved with a much lower initial investment being required.

SCENARIOS

The following chapter describes four scenarios of different futures. The chosen scenarios are plausible, relevant, and of consequence for the user's decision, challenging, internally consistent, and recognizable from the signals of the present and near future. All four scenarios described below are equally plausible, extreme visions of how the Digital Future of the Construction Industry might shape our lives in the year 2050 with regards to two key drivers. Stories of personas experiencing a day in 2050 are used to envision the scenarios. Signposts (often described as weak signals) that indicate a development towards each scenario are identified in order to describe a possible path from the present to each of the four extreme futures.

DRIVER MATRIX

Based on the research conducted throughout the Basic Phase of the Trend Seminar, drivers for the future development of the construction industry were identified. Drivers are forces that frame the future of construction and are usually exogenous to an organization. Identified drivers are modelled with bipolar extreme outcomes.
The matrix on the right ranks the identified drivers for the construction industry according to impact and degree of uncertainty. Based on these dimensions we have selected two key drivers that help us describing future scenarios: Customization and Fragmentation. Within the matrix, they are highlighted in green. The following pages contain a detailed description of the respective key drivers as well as a brief overview of all other high impact and high uncertainty drivers. Finally, the subsequent scenario matrix illustrates which scenarios describe the four outcomes of these key drivers.



KEY DRIVERS

Market Structure

Fully Fragmented

In this extreme scenario, the construction industry is fully fragmented. According to a report from the World Economic Forum in 2016, the European and especially the German construction industry have always been very fragmented [REN16]. The degree of fragmentation in the construction industry would be further aggravated by 2050. There is no firm with market dominance due to the large number of companies, resulting in each of them having only a relatively low and unstable market share. In this case, the competition is fierce and price-driven, and the investment in R&D becomes scarce.

The concept of a market structure is understood as those characteristics of a market that influence the behavior and results of the firms working in that market. The main aspects that determine market structures are: the number of agents in the market, both sellers and buyers; their relative negotiation strength, in terms of ability to set prices; the degree of differentiation and uniqueness of goods and services; and the ease of entering and exiting the market. One of the most influential factors is picked to picture the scenarios of the construction industry in 2050, which is the number of construction companies in the market.

Fully Consolidated

In this extreme scenario, the construction industry is fully consolidated with two or three big construction companies making up over 90% of the total market share. Small companies are left covering niches, without any real influence on the overall market. New entrants stand no chance of competing with the incumbent companies. Since a balance of power ensues between the big companies, expansion can only continue vertically through the integration of all business processes. The 'winners' are formed either through mergers and acquisitions or through natural expansion with the advantage of efficiency and high reputation. There is intensive competition among the giants, but the large companies are almost robust in the face of global changes and developments.

Customization

Fully Customized

In a fully customized setting, each project is adapted to the respective customer's preferences. The construction process is highly mechanized and can be modified at any stage. The roles of humans shift away from the production itself towards design-related tasks, leading to a wide variety of designs chosen out of an infinite number of possibilities. Full customization entails more iteration cycles, emphasizing the need of humans for the resulting increase in communication. This scenario is mostly driven by the desire for self-fulfillment, aesthetics, and functionality, expressed by the demand for rare materials, unique features, and exceptional designs.

Advancements in technology have enabled companies to study the needs and choices of customers and to communicate with them individually, rather than talking to a whole segment of customers. Collaborative modelling tools and additive manufacturing technology reduce both time and costs and, thus, allow for changes to be implemented quickly, which leads to more product variation. Therefore, customization describes the integration of customer preferences into production processes. This way, individuals can be connected with objects that reflect their personal style or life choices. In the context of construction, it refers to the degree of customer integration into producing material units for residential, commercial, and publicly used entities. The term "entity" is intentionally kept broad to account for changing living and working concepts that can radically differ from current forms.

Fully Standardized

In a fully standardized setting, practicality and efficiency are the main drivers for product design. The ever-increasing population in urban areas combined with resource scarcity will drive the need for affordability and space efficiency. This leads to modular buildings optimized for space efficiency that are identical in size, shape, and color. Due to already implemented and previously existing infrastructures such as 3D models and material supplies, economies of scale and long-term supplier relationships can be made use of to foster time and cost efficiency.

OTHER DRIVERS WITH HIGH IMPACT AND A HIGH DEGREE OF UNCERTAINTY

Extreme Immobility People do not travel for work or leisure.	← Need for Mobility →	**Extreme Mobility** People very frequently travel long distances.
Extreme Labor Shortage There are no workers available.	← Human Labor Supply →	**Extreme Labor Surplus** There are many workers available for each position.
Low Energy Cost Energy costs are close to zero.	← Cost of Energy →	**High Energy Cost** Energy costs are exceedingly high.
Closed Borders There is no migration to Germany.	← Migration →	**Open Borders** Germany has open borders, allowing anyone to immigrate.
No Value-Chain Integration Companies focus on only one step of the Value-Chain.	← Value-Chain Integration →	**Complete Value-Chain Integration** Companies cover the entire Value-Chain.
Unattractive Nobody wants to work in the construction industry.	← Industry's Attractiveness →	**Attractive** Everybody wants to work in the construction industry.
Renting Everybody lives in a rented residence.	← Housing Ownership Model →	**Owning** Everybody owns their residence.
Complete Counter Urbanization People decentralize and move to in rural areas.	← Urbanization →	**Complete Urbanization** People flock to urban areas, creating mega-cities.
Cheap Building Materials Building material costs are close to zero.	← Material Cost →	**Expensive Building Materials** Building material costs are exceedingly high.
Isolationism All countries avoid contact and exchange of ideas and culture with each other.	← Political Climate →	**Globalism** All countries promote contact and exchange of ideas and culture with each other.

SCENARIO MATRIX

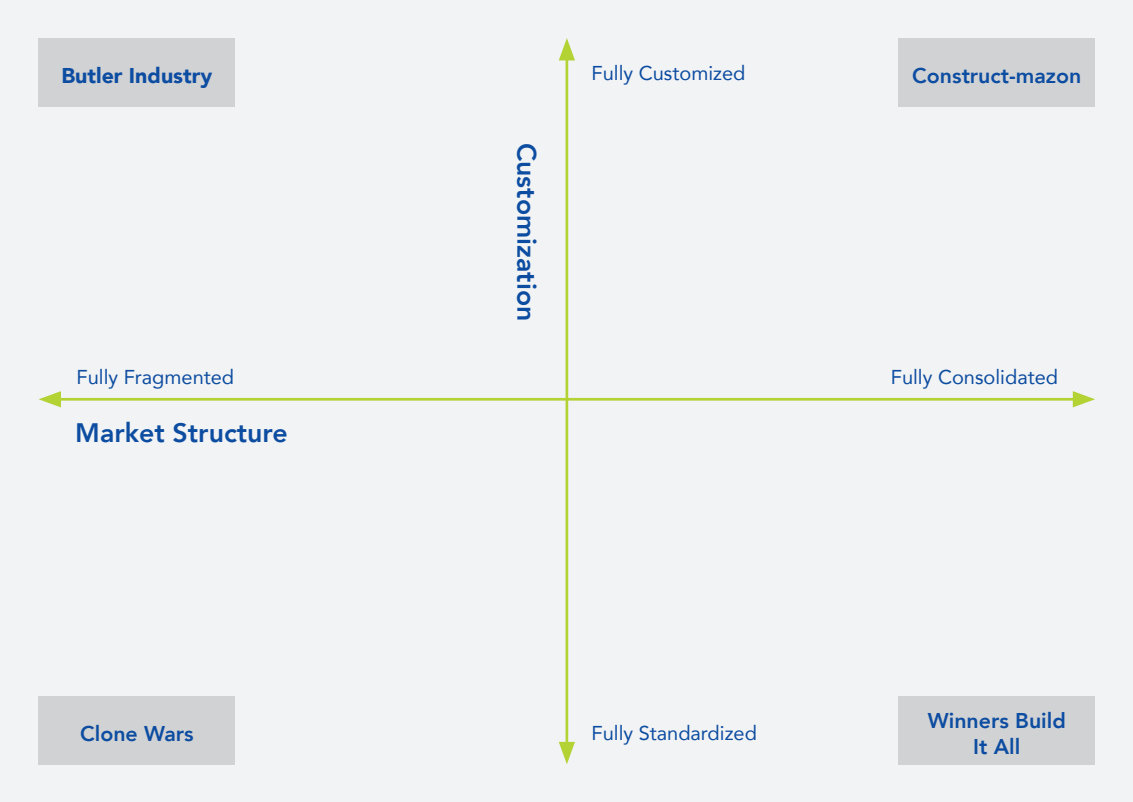
The two key drivers and their outcomes create a scenario matrix. Each key driver represents one of the axes, with bipolar outcomes on the respective ends. All four scenarios are based on extreme outcomes of both key drivers. Plausible and consistent outcomes of other important drivers are included in each scenario, but not taken to an extreme.

"Butler Industry"
A world, in which the construction industry has become even more fragmented than today, due to more freelancing and cheap technologies. Individual customer expectations are very demanding and can be met individually using technologies, such as 3D printing.

"Construct-mazon"
A future with a fully centralized construction market where customers require high means of customization options.

"Winners Build It All"
A future referring to a centralized market with high standardization across offered building products.

"Clone Wars"
This scenario implies a heavily fragmented market with plenty of participants offering standardized solutions.



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BUTLER INDUSTRY

A day in 2050

A modern cottage in the Allgäu region with a wooden terrace, a friendly garden, and a spacious garage for their self-driving car – this is what Christine and her spouse have always dreamed of, and today, it will become a reality. Christine wakes up with a big smile on her face. She gets dressed full of excitement, puts on her AR glasses, and grabs a quick smoothie before she leaves for the high-speed capsule train from Munich to Allgäu. When the government started to build this new network of high-speed capsule trains, Christine and her husband immediately bought a lovely property in the countryside. Like all of her friends, Christine follows the Build it Yourself (BIY) trend and wants to have a unique home with individual style. Through 3D printing technologies, customized houses are on the rise. For example, a befriended couple just built a gorgeous house in a Swedish style.

To fulfill her dream of a modern cottage, Christine designed a 3D model in the BIY app together with her husband. Right after they uploaded it to the BIY platform, they found their perfect match – Peter, a freelancing project manager and designer with experience in modern houses. Christine and Peter have continuously cooperated remotely on the BIY collaboration platform to virtually design and construct the residence of her dreams.

When Christine arrives in Allgäu, she can't wait to meet Peter in person. Stepping out of the capsule, she closes her eyes and takes a deep breath to soak in the fresh air of the countryside. It's still hard for her to believe that this is not just a vacation, but will soon become her everyday life. She understands why all doctors recommend people nowadays to move away from the polluted cities into small villages. On the other side of the capsule track, she sees a man waving at her. Soon, her AR glasses recognize him: It's Peter.

Waiting for Christine to come to the other side of the track, Peter's thoughts drift away. He has been a professional designer and construction project manager for more than ten years now. Most of his project experience consists of planning and supervising private modern style houses. His primary duties concern fulfilling the client's wishes and ensuring technical feasibility. Due to the simplified local building laws, EU citizens' diversity can be reflected more easily within their designs. He is also responsible for maintaining the initial cost and time frame. It is imperative for him to be at the customers' side from the beginning until the end of the construction project. It fascinates him, and he feels very proud whenever he can respond to the wishes of his customers and see them happy after moving into one of his finished buildings. Usually, the first meetings and discussions take place virtually via the BIY platform. Later, there is commonly one physical meeting to discuss the final details of the building.

Using Christine's drawings and her basic model he was able to develop a full digital twin of the future cottage. Through AR, he showed her the modeled 3D version of the building, the garden, and even the surrounding areas. Not only the outside view but all rooms inside the building, as well as the preferred furniture, were visualized. Today is the final meeting to make any changes before the construction phase starts. Further change requests can still be applied during the construction phase as the overall process is designed to be highly flexible until the very last second. However, through VR, customers have a sound idea of the future building, which reduces critical change requests to a minimum.

After Peter introduced himself to Christine, they walk to one of the autonomous cars in front of the train station which

drives them to the construction site. On their way, Christine and Peter discuss some final details. Peter can rely on his many years of experience, and AI helps him with the design aspects by for example showing warning messages if specific ideas have not met long-term customer satisfaction in the past. Every time a final version is ready, Peter feeds the 3D model into his online building platform. The platform's smart algorithm is calculating labor, raw materials, and machinery required to build this project. Additionally, a structural analysis is computed.

In the middle of the discussion, the autonomous car starts to slow down. Peter and Christine take a glimpse outside the window. They spot the property surrounded by some trucks and machines. Finally, the car smoothly stops in front of it. Leaving the car, Peter introduces Bob, the construction worker responsible for supervising the construction site, to Christine. Peter found Bob via an online marketplace. Online marketplaces are essential to get an overview of the current situation, and the availability of labor, raw materials, logistics, and machinery. Peter is eager to balance workforce and hardware to get the best cost-value ratio. After Peter has calculated the cost frame, he allocates the resources. It allows him to hire co-workers through a global freelancing platform and select them based on experience, rating, and availability. Peter decided to hire Bob for this project because of his expertise and stellar reviews on the platform. For more than 30 years Bob completed hundreds of construction projects. He grew up in Munich and was used to the hard manual work related to his job, but he also adapted to the new digital era on construction sites.

After getting to know each other, Peter, Bob, and Christine put on their VR glasses and walk around the displayed house. As they pass the northern side of the building, the building AI alerts them that too little sunlight is getting through into the bathroom. Peter recommends using taller windows with a special glass material that is only transparent from the inside. Christine agrees to the proposed change, and they add it to the model.

Christine recognizes that she is not yet sure about the placement of the door in the living room. Insecurely she approaches Peter who, after talking to Bob, reassures her that change requests can be incorporated throughout the whole construction process until the respective parts are built. Nevertheless, they decide to move the door, and Peter quickly implements these changes into the model which syncs with the project management app. Afterward, it is pushed to Bob's devices and machines. The project management software already scheduled which machine has to work in which time slots.

As advised by the project management software, Bob starts to sync the model with his digger, which starts by autonomously digging the hole for the basement. Simultaneously he starts up his construction machine, which is an adapted version of a 3D printer. It can move itself and layer concrete in a very accurate and fast manner. Bob configures the machine for the project-specific materials – adapted to the wishes of Christine. Relieved and proud of her design, Christine finally watches the digger begin its work.

After the digger has finished, the construction machine moves to its starting point and Bob instructs the crane on the truck to supply the construction machine with the materials. He remembers the old times when he had to use heavy machinery himself. Nowadays he can use small devices with intuitive interfaces to operate all the big machines. His younger colleagues are very different, rather slight and don't know how work was 30 years ago. He is happy that times have changed because now he can treat his body with care while working more efficiently than ever before.

While the 3D printer is starting with the first layers, he checks the schedule of the project and sees that all missing resources, such as the painting robot, the prefabricated roof, and the furniture, will arrive on time. After the 3D printer has completed the first layers of the house, Bob employs his drone to capture the first real-time data to compare the progress with the digital twin in the project management app. For now, his 3D printer works flawlessly.

In the evening, Christine meets her husband for dinner and is happy to share her experiences with him. They are both delighted with the freelancing atmosphere within the construction industry nowadays. It is an excellent feeling that Peter carefully considers and value their ideas. As a freelancer, he can entirely devote himself to their dream house, and they know, that their future home is in good hands.

Signposts

- New EU tax legislation heavily supports freelance work and entrepreneurs
- 3D printed houses are now cheaper than manually built houses
- New regulation reduces weekly work time to 32 hours
- Due to the EU campaign "United in Diversity" cultural diversity increases, and individual housing styles are on the rise
- The German parliament simplifies municipal building law and allows more design flexibility
- For the first time, more people are self-employed than in traditional employment relationships

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COSTRUCT-MA-ZON

A day in 2050

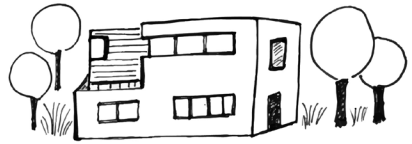
Impatient fingers are drumming on the glass table. "Mrs. Kumar is getting nervous," Anna thought. "We have not talked about the treadmill yet, Deepak," Mrs. Kumar, Anna's new client said while giving Anna a look of high expectancy. "We want to have this treadmill built into the balcony. We requested this feature at Morrisons, but it would have taken them ages. How about you, are your partners able to build that until we move in?" Anna forms a smile. The last years have been a head-to-head race for market leadership in the construction industry between Morrisons and Forstner & Söhne, Anna's employer. Until now, it has been a tough conversation with these new clients. Now, it is up to her to close the deal, and the prospect of yet another win against Morrisons fills Anna with contentment. Mr. Kumar was impressed as soon as he entered Anna's glazed office and studied her business card thoroughly for the hundredth time. Customer Success Manager. That sounds impressive. Soon after he had moved from India to Germany with his family to work as a software specialist, he had contacted Anna and talked in detail about the house he wants to build in the outskirts of Munich. Anna looks down at her notes. The house as it is planned now differs considerably from the one he originally described on the phone. Mrs. Kumar obviously has an assertive personality. Anna decides not to comment on that and, instead, leans forward and explains: "We have great connections to the RunRZ Lab which has the best treadmill on the market currently. It even corrects your running style. Plus, it scans your body and suggests post workout meals according to your performance and goals." She taps on her massive glass table, and Mr. Kumar's eyes start to shine. He had not realized yet that there was an integrated tablet computer which was now displaying a highly detailed outline of his future house. Anna continues: "They can deliver in about three weeks so that there is no delay for you to move in. Let me show you what it will look like". She hands over VR glasses to the couple and a few seconds later, Mr. and Mrs. Kumar are exploring their future home. Anna already knows that they are about to close the sale. "Thanks to the data we have generated about how happy our customers are and about how they use their houses, our algorithms have already optimized your floor plans to suit your needs. Moreover, this will hold not only for four weeks. Over 97% of customers are still as happy as they were on day one after five years", she explains with a highly professional voice and smiles even brighter. The superior new way of software-supported construction has always been the competitive edge allowing Forstner & Söhne to build and sustain their strong market dominance. After discussing the instantly calculated construction costs, Anna's clients sign the contract electronically. Even before they finish their glass of champagne, the digital table beeps, indicating that the project status has been updated. The local building authority has validated the purchase and the transfer of land and money has been booked on the official blockchain register. They will

start with construction immediately.
Soon after Mrs. and Mr. Kumar have left, Anna grabs her handbag and heads to a construction site 40 km north of Munich. She walks towards the suspension railway station which opened recently, the biggest infrastructure project for years in Munich and a massive triumph for the Greens in parliament. That Forstner & Söhne manages this project caused Anna to receive a lot of appreciative comments from family, friends, and former fellow students who work for different firms in the construction industry. Forstner & Söhne was one of the first companies that recognized the need for individual solutions. As a result, highly specialized engineers were hired, and contracts with software firms were signed to enable a high degree of collaboration between humans and machines on-site. Of course, there are also progressive competitors these days, and Anna usually considers herself lucky being in such an exciting high-tech business with a decent salary and numerous chances for self-development. She can schedule her week flexibly and almost always makes it to her yoga class at seven. However, Anna sometimes doubts if all the years of studying both computer science and design were worth the effort, given that her job now consists primarily of fulfilling the oddest wishes of clients, which are not even put into practice by her, but by technology. Anna dismisses these thoughts as she steps into the wagon and feels her phone vibrating in her bag. It has just recognized the light barrier and automatically paid for the ticket. Anna sits down and takes a deep breath. "It is crowded today," she thinks. "Everybody seems to be constantly on the move." There are lots of voices, lots of nationalities around her, but Anna does not hear it.
The first thing Anna notices when she arrives at the construction site is the progress that has been made during the previous days. The wooden external cladding has been installed, and some 3D printers are coating the roof with a thin layer of solar panels. The panels have become mandatory for new buildings as energy prices have risen dramatically over the last decades. Anna likes the idea of the clients to integrate trees into their home instead of removing them. That is the best part of her job, observing how these unique homes grow step by step. Anna turns away from the building and notices that only a few people are busy steering the robots installed on-site. She heads towards the office container and finds her on-site colleagues in a little gathering. "Anna, glad to see you! Can I offer you some cake?" Frank, an adjustment officer, whose job is to adapt all machines and robots to the different conditions on-site, walks across the room to welcome her. At this moment, Anna notes the "Happy 72nd Birthday" garland and the chocolate cake. She prevents herself from breaking out into laughter: Six on-site workers still wearing their exoskeletons are struggling to eat their cake with forks. They nod to Anna. "Frank, good to see you. Happy Birthday", she says, "thanks for the offer, but I am actually in a hurry. Just wanted to have a quick chat with Juan. Is he available?" Frank points to a door on the other side of the room. "He's in there." Anna could hear the slight disappointment in his voice.
"It's like an orchestra." Juan casually folds his hands behind his head and puts his feet on the corner of his desk. "It's like an orchestra and I am the conductor." Anna was grinning. During her long-term cooperation, she always liked Juan's light-hearted personality and self-mocking character. "Is it that bad?" she asks rhetorically and sits down on one of the chairs in front of Juan's desk. He smiles at her. "Well, there are a lot of highly complicated tasks and they all require their slot in the schedule." Juan's head points toward the screen next to his desk. Anna recognizes all the icons for machines and engineers subcontracted to specialist companies for the current building project. She has always been fascinated by this communication system documenting all status updates, deadlines and critical tasks. It is even connected to the robots on-site, enabling a live-simulation of the ongoing construction project. "It is Juan's role as project manager to supervise the workflows and improve quality management on-site," Anna thought, "Juan knows the technology and is an absolute expert in his field. Not many people can fulfill the requirements and experts like Juan are in high demand. For sure, he must have been headhunted and offered a lot of money". She adds: "And our subcontractors' invoices are skyrocketing." Juan scratches his beard. "Yeah, I mean, the government can sign as many trade agreements as they want, it is still expensive to get the special sandstone from India, it is simply not a mass market like concrete. Although concrete is already relatively expensive.", Juan realizes, "Do you want a coffee?" When Anna shakes her head, Juan takes a sip from his coffee and puts it back on the table, indicating

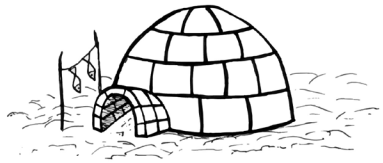
that small-talk was over now. For the rest of the afternoon, they talk through the particular tasks that are necessary to fulfill the requests of the Kumar couple.
Heaven has turned dark as Anna leaves the construction site. The wind is cold, and leaves are whirling around her. The robots are still covering the roof, unimpressed by the arising thunderstorm. Anna jumps into her ordered air taxi. She almost arrives at home when her tablet suddenly vibrates.The planning system informs her that due to the heavy weather conditions, all robots need to stop operating tonight. The estimated project termination is one day later than planned. Anna sighs. "We let robots build our homes, but nature can still hold us back."

Signposts:

- Number of megacities (cities with >10m inhabitants) surpasses 70 globally
- Emerging need for cheap and space-efficient buildings in urban centers leads to the mandatory use of modular building principles for high-rise buildings
- Over 95% of high school graduates pursue an academic degree
- Countermovement: Increasing adoption of social media and wealth leading to societal narcissism and urge to individualize
- Introduction of the universal basic income in Germany for citizens over 40
- High automation of actual construction and use of adaptable machinery and additive manufacturing reduces construction costs of customized buildings (batch size 1)
- New worker safety regulation forbids on-site work without exoskeletons
- High demand for customized solutions leads to aggregation of the market by companies who developed the intellectual property to drive this innovation and standardized competitors are driven out of business
- Last modular house in Jena turned into a museum to emphasize how vital individualization is to the present generation



Let me fulfill your dreams...



Mihai Babiac, Shiv Contractor, Eileen Einwächter, Simone Kilian, Mathis Stolz, Jingchen Wang, Till Wiechmann

WINNERS BUILD IT ALL

A day in 2050

The morning sun is shining brightly through Pranjal's window as the alarm clock wakes her up. She eagerly opens her eyes and gets ready for her first day at the new job. After all the stressful applications and interviews, she has finally landed her dream job at Build.io, one of the big three construction firms.

"I called you a taxi. It will arrive in 3 minutes," Pranjal's virtual assistant says to her. She grabs her usual freshly baked croissant and coffee from the robot cook and heads outside. Looking around, she is greeted by the already familiar sight of the new neighborhood. It had taken a while for her to get used to the repetitive pattern of identical buildings when she first moved in two months earlier, but now after she had settled in, she likes it.

The taxi arrives, and Pranjal gets in, smiling politely at another person inside. Looking out the window, she reminisces about her childhood memories, when cars were not self-driving and usually weren't shared. She thinks to herself, how inefficient and dangerous that must have been.

"I don't mean to be rude, but do you happen to live in one of the B+ houses?" the man next to her asks, interrupting her train of thought.

"Yes, actually, I just moved into one recently," she replies. The man tells her "I'm thinking of upgrading from a B and even after reading tons of reviews, I would still like to have an unbiased opinion of someone who's actually lived in one." "I don't think I'd be the best person to ask; today I'm joining Build.io," says Pranjal grinning at him. "Oh, I hear it's a great place to work. Congratulations! I'll risk assuming you haven't put on your fangirl hat yet. Would you recommend the switch to B+?" asks the man. "For me it was definitely worth it, but if I were in your place, I'd just try it. They've recently started offering a trial program," Pranjal says. "Trial program?" he asks. She finishes: "Yeah. You can test the upgrade for free for a month. Just send the request and they will move all your things to the new address in just half a day. Alright, this is where I'm getting off. It was nice talking to you." "Likewise! Bye and thanks for the tip! I'll check it out for sure," the man responds.

Excited, Pranjal steps out of the taxi and looks up to where she will be starting her first job. Directly in front of her is an impressive skyscraper with the famous Build.io logo on top, casting a long shadow on the surrounding buildings. Young people holding coffee move quickly in and out, chatting about the performance of their departments, data sets to be analyzed and corporate gossip. Pranjal inhales deeply, mumbles some motivating words to herself and enters the lobby. After being welcomed by the digital office assistant and moving up to the 43rd floor, she gets introduced to Lisa,

her new supervisor: "Welcome to Build.io, Pranjal. We're glad to have you on board!" Lisa opens. Pranjal thanks her and continues: "I am really looking forward to working here!" "Good to hear that! Let me give you a quick introduction tour," Lisa replies. While walking through the different departments, Pranjal notices several dashboards, open working areas, and people in virtual conference rooms. Lisa continues while walking: "In your role as Junior Manager, you will be responsible for monitoring both our existing as well as newly built quarters and analyze the data we generate to enhance overall customer satisfaction. Your payment is proportional to your performance, i.e. based on the subscription churn rate of your community - but you already know that, right? At Build.io, we do not just rent out space, we sell a lifestyle: Flexibility, a community worth living in, and affordable luxury for everyone. After the third migration wave, we were forced to come up with affordable living solutions which can be built very fast."

Pranjal responds quickly: "Oh! Yes, I remember very well. My family arrived in Germany around that time." Lisa follows up: "So, I'm guessing you've probably already lived in one of our buildings – what a great story! Anyway, since we realized that construction is only one vertical of a huge market to be targeted, we decided to reposition ourselves as a living as a service (LaaS) provider, covering all market segments. And now, look at us! The LaaS market is a tough game, but we are proud to be the only company left to have evolved from an actual construction company. By the way, did you have lunch yet? Unfortunately, I have a meeting, but you could join Tom – he is one of the guys in charge of setting up the new communities. Good luck, Pranjal!"

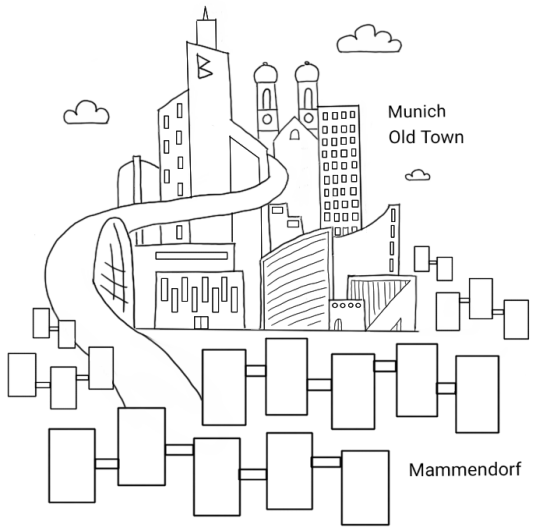
Over lunch at a delicious Falafel place, Pranjal's new colleague, Tom, walks her through the way standardized houses are built and why they are efficient: "I coordinate a construction project, which uses autonomous trucks, humanoids, 3D printers, and drones as resources. These help us to work on projects 24 hours a day. And since energy suppliers offer a cost flatrate, the onsite workforce is cheaper than humans. Which is very convenient, since we were struggling to find human labor supply for quite a long time now." "How many humans are still working directly on the construction site?" Pranjal ponders. Tom responds: "Well, last year the last human worker on site retired. Currently, it's done completely humanless and remote controlled. Therefore, all the earlier human workforce is shifted to office work and robotics labs to a great extent." Astonished, Pranjal concludes: "So, the houses must be cheaper than I thought." Tom gets excited: "Well, even though the material costs are still extremely high after the steep rise in 2035, the buildings are cheaper than earlier, since houses can be built faster now. Still, most of the cost is material-related. Unfortunately, I have to go back to work, but let's chat tonight at the 'Meet the New Employees' Event?" "Looking forward to it! I'll be done setting up by 5 o'clock anyway", replies Pranjal.

That evening, at the party, she is introduced to Jeffrey, one of the senior executives at Build.io. He asks her: "Where are you from, Pranjal? Are you from Munich?" "No, I'm actually from India, but my family moved to Germany when I was a child, right after the Treaty of Dhaka, phasing out the need for a visa. I've been in Munich since April," she responds. "Then, I guess you're in one of the new neighborhoods?" he replies. Pranjal smiles: "If you call the entire standardized belt around the city 'new', then yes. I live in Mammendorf, in one of the inner rings. What about you?" After some seconds, Jeffrey responds: "Have you seen the Ludwig Beck building in the old town? I live right across it." Pranjal: "Oh, so you're one of the old schoolers. I can't picture myself living in that part of the city. Doesn't it bother you that it takes forever to get a cab there? Don't you miss all the services? I couldn't afford to live there anyway..." "Well, of course it can be annoying sometimes, but you know, I grew up there and I own the place now. Also, I have a lot of memories associated with the old houses."

After having a long conversation, they leave the lounge and head back home. As she arrives back at her neighborhood and passes the surrounding buildings she recaps everything she experienced during her first day. "It's so nice," she thinks to herself, "being part of the company who built all of this."

Signposts:

- 90% of residents adopt flexible rent models
- 85% live in densely populated urban areas
- New migration increases pressure for social housing
- New regulations limit the size of new flats in overpopulated cities
- Hyperloop One replaces the last intercity train
- Over 60% of workers at construction sites are robots
- Build.io launches printable houses selling for as low as 15.000 EUR
- EU mandate: Standardized buildings necessary to meet energy efficiency targets
- CO2 levels hit record-low since 1990
- 2035: Alarming shortage of utilizable sand



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CLONE WARS

A day in 2050

The alarm starts to ring quietly. Franz Betzinger tries to open his eyes carefully but immediately squints as the bright sun rays seeping through the Venetian blinds dazzle him for a moment. "Good morning Franz! It's 6:45 am and the weather is wonderful this Wednesday, it's time to get up," the pleasant voice of his virtual home assistant remarks. Franz, with his eyes still barely open, follows the advice after some yawning and moves the few steps from the bed to the bathroom. "Alexa, how are Jane and the children?" he mumbles. "They're fine. They have just reached your parent-in-law's house in London. Franzi and Kai are playing with the new HoloLens." Franz blurrily remembers that his wife and kids kissed him goodbye about two hours ago. He shuffles to the kitchen and once more notices how much larger it is than the one in his previous apartment. "Incredibly expensive," he reflects, thinking about the excessive price of this 100 square meter apartment which he moved to six months ago.

After finishing his cereal, he commands Alexa to switch off his favorite news podcast. Like on all working days, the driverless taxi waits for Franz in front of his apartment building in southeast Frankfurt. He never looks at his smartphone during this five-minute ride but rather enjoys dreamily gazing at the apartment buildings and houses in this area. They are all cubicle-shaped, and most of them have a green garden surface on the roof. Aside from their color, size, and some other individual elements, they all look the same; especially to Franz, the director of a small construction company called Betzinger. Franz likes the homogeneity of his neighborhood, but he is still fascinated by the more individualistic style of the very few buildings constructed before the new regulation. The German government passed the construction efficiency act standardizing material, size, and shape due to proven environmental and economic efficiency benefits. Shortly before arriving at the Hyperloop station Frankfurt-East, he sees the father of Francis' best friend Mesut jogging. Franz feels sorry for him as he just lost his job as an architect. Architects are barely needed anymore, and occupational retraining to a structural engineer is quite expensive and time-consuming. "We have arrived. The next pod to Munich leaves in five minutes," the voice of the taxi interrupts Franz' thoughts.

As usual, on his 20-minute ride to Munich, Franz reads the daily news on the screens in the Hyperloop pod under the murmur of mostly English conversations of the other commuters. "Frankfurt breaks the mark of six million residents and now ranks as the 5th largest German city," the headline, which caught Franz' interest the most, reveals. He arrives in Munich at 7:50 am, right on time for his meeting with Stefanie, the company's sales manager. Betzinger offers end-to-end solutions for apartments and houses, using different contractors to complete each step of the process. They only construct new buildings and don't undertake very complex and time-consuming renovation projects, which some of the other construction companies do. Such a project could last up to three months, whereas the construction of new buildings never crosses the time limit of four weeks. Moreover, renovation permissions take at least two months for approval, whereas for new buildings it takes only a few days after applying on the municipal construction planning website. Betzinger's twelve employees are project managers, structural engineers, and resource, logistics or sales managers. The physical work is performed mainly by rented construction robots, supervised by freelancers.

Entering the office of Betzinger, Franz greets the receptionist and goes up to the second floor, where Stefanie awaits him at his desk. "Hope you have some good news for me?" he asks. "Some are good, some are not so good," Stefanie replies before informing him about the current sales progress. The information about a rejected public tender offer spoils Franz' mood: "How is it even possible that Euro-Bau came up with such a low price?! How can they undercut our offer with current concrete and energy prices? I mean, the production costs are the same everywhere!". Competition between the different construction companies in the booming metropolitan areas in Germany is quite fierce. SMEs specialized in specific construction processes dominate the market niches. "Have enough freelancers applied for the construction site

in München-Pfaffenhofen?" Franz asks. "There are still two vacancies online at iConstruct. However, all vacancies should be filled by next week," Stefanie answers confidently. Franz has thought several times about hiring new employees, but on-demand freelancers skilled in operating Betzinger's building robots are the cheaper option. Furthermore, due to the uncertainty of the future demand, he is not willing to hire with the strict labor laws a company has to follow for permanent employees.

After a cup of coffee, Franz puts on VR-glasses and swipes with a hand gesture through the different projects in which his company is currently involved. As long as the little sign in his upper right field of vision lights up green, there is no need to worry: everything is working as planned. Sometimes he still commands the tool to provide him with project-specific data or forecasts. Even though the tasks and observations are usually the same, he deems this routine necessary, as the partners of his company change for every project.

One construction project in the virtual list, however, lights up red. An automatic voice immediately tells him that one construction machine stopped working: A worker did not prepare the ground of the construction site properly, leading to the machine accidentally getting stuck and breaking down. Usually, there is no need for Franz to go on-site as processes are standardized and run quite smoothly. This time, however, he has to go. "I will give this guy a bad rating," he mumbles while ordering a taxi.

On the way to the construction site, Franz quickly checks the current status on his phone. Two subcontractors have already finished their job and sent him the invoices. After checking their work using his VR live stream, he approves their performance, and they receive their payment. He also notices that the remaining eight subcontractors simultaneously working on the site should be able to finish their work by the end of the day. A bit more relaxed about the overall process of the project he exits the taxi. He suddenly feels vibration and quickly takes two large steps away from the gateway. He did not notice the oncoming autonomous truck transporting one of the main wall components from the prefabrication factory.

Arriving at the construction site, the truck smoothly stops, and one of the workers on site instructs a robot to take over the offloading. Even though autonomously functioning machines and robots have relieved human workers from hard physical work, the industry's image is bad owing to the strenuous and poorly paid work on the construction site.

Finally, the technicians from the robot provider call, stating that they will arrive on-site in five minutes. Franz hopes that they can fix the machine quickly so that Betzinger does not face overruns in time and cost and can avoid the high contractual penalties for delays. Since the rented machines are highly complex and require in-depth operational expertise, Franz relies on the assessment of the specialists. Because of the pressure to finish the house on time, Franz is visibly stressed. Franz reminds himself of the fact that the option to rent these machines instead of investing much money in purchasing the machinery, allowed him to start his own construction business. He manages to calm down and leaves behind his anger about the high dependency on the various micro-players in the market. In the end, the technicians fix the robot within fifteen minutes because of their high expertise and streamlined, standardized processes. However, the workers on-site need to stay longer and Betzinger has to cover the expensive overtime.

After finishing work, Franz visits his father in a shared assisted living. They reminisce about how the construction industry has changed since Franz's father was a construction worker. His father dislikes how the construction site has developed to a factory-like building process, where everything is automated and timed to the second. Franz's father tells his son about how excited he and his wife were when they moved into their first house and how saddened he is by how little people care about their houses since people have stopped buying. Back in his day, people had an appreciation for their home; today people only rent their home and see it as something that has to be as efficient as possible. While going to bed, Franz thinks about the industry he works in and how it has changed. Even though he dislikes many parts of the industry, he is still grateful that he has a positive impact on society, environment, and people's lives.

Signposts:

- Government centralizes R&D for the construction industry and increases its investments
- Big players in the construction industry failed to compete with the symbiosis of agile SMEs and freelancers
- New record high: Never before seen number of SMEs in the construction industry
- Over 90% of construction companies now use an online platform for hiring subcontractors and machinery
- The government further strengthens labor laws and minimum wage, making the use of freelancers more profitable than hiring staff
- 30% of the Netherlands is under water due to the effect of climate variations on water bodies, prompting new environmental construction regulations in the EU
- Standardized construction methods and processes make building 10-times faster

IDEATION

The following chapter describes five novel business models in the field. Each of the business models is described using the Osterwalder Business Model Canvas.

Saad Amin, Kaya Dreesbeimdiek, Kilian Egger, Joana Haase, Lucian Riediger

CONAS

A Virtual Audio Assistant for On-Site Efficiency

Conas is a cloud-based audio assistance designed for on-site construction workers. With Conas, they are supported in extracting information from complex construction plans and, hence, in delivering their assigned tasks efficiently and according to requirements. Construction plans are usually developed as 3D models in architectural software and – in a steadily increasing number of cases – implemented in BIM. However, on construction sites, workers still rely on 2D paper-based plans as a source of measurements, material information, and interior object location. Conas provides a digitized solution in translating the information of a construction plan into audio.

From a technical perspective, this solution is enabled by the Conas design-to-speech software. Architects and construction companies upload their BIM and CAD design files to the Conas cloud, which translates every detail of the plans into natural language. The audio of this text is accessible via a smartphone application. Similar to speech assistants, such as Amazon's Alexa, construction workers can ask Conas for information about the plan such as measures and materials. Additionally, construction workers can leave comments, e.g. in case of flaw detection. To play the audio and to enable smooth operation, Conas offers noise-canceling earphones and microphone as an optional product bundle. However, the app can connect to any Bluetooth-compatible headphones.

The design of the Conas assistant allows for several functionalities: On the one hand, construction workers can receive information from construction plans while using their hands for the current task. Workers can ask for specific measures or materials without consulting the plan visually or having to recall mental notes. On the other hand, several application programming interfaces (APIs) enable additional services. To overcome language barriers on construction sites, we offer the audio pieces in multiple languages. In addition, text-to-speech services allow construction workers to communicate with the app for the sake of documentation.

The target groups are construction companies of all sizes as well as subcontractors on-site, who are supported during the onboarding process and subsequent project phases. Customers sign up for the service via a monthly subscription for each account. Thus, Conas offers its service to a wide range of firms contributing to the construction process.

Business Model

Key Partners

- Software and API providers
- Architects and construction firms
- Project owners and project developers
- Hardware supplier

Key Activities

- Development and maintenance of design-to-speech software and interfaces
- Acquisition of software service providers and development of APIs
- Customer acquisition and development of relationships

Key Resources

- Human Capital
- Design-to-speech software and data
- Additional software interfaces
- Hardware

Value Proposition

- Easy access to information from construction plans
- Higher accuracy through controlled information flow
- Greater safety during the workflow
- Removal of language barriers
- Documented errors

Customer Relationships

- Setup support and training via learning videos
- Key account management
- Customer support via app or telephone
- Product review via the app

Channels

- Direct mailing and company visits
- Construction fairs and trade journals
- Through project owners and project developers
- App stores and online sale of hardware Construction workers

Customer Segments

- General contractors
- Subcontrctors and specialists
- Construction workers

Cost Structure

Fixed Cost

- R&D Investment
- IT infrastructure
- Office space and further work equipment

Variable Cost

- Sales and marketing
- Customer support

Initial Investments

- Software development
- CAD / BIM consultation
- Legal advice

Revenue Streams

- One-time setup fee for translation of construction plan to speech
- Subscription model depending on the number of accounts
- Hardware components Individual contracts

Value Proposition

Constructions plans are becoming more complex due to regulations and customer requirements. For example, with the increase of smart homes, unfamiliar requirements arise for the worker. Adhering to these requirements means that the workers must be able to extract the correct information from constructions plans. Conas allows users to obtain any information from the construction plan without having to lay aside construction tools, take off gloves or unfold the plan itself. As Conas is based on audio, the user can continue working with his hands while receiving information.
Conas provides any detail required at any point in time during the workflow. This controlled flow of information makes it easier for the workers to understand the construction plan as they are no longer overwhelmed with a lot of information from the paper plan. Conas can help any user of a traditional paper plan, from a driller making holes to a worker installing windows.
The product also allows the worker to make comments or observations while working. These comments are saved and also available to the supervisor who can then decide how to act on them. This feature allows for a smooth flow of information between workers and supervisors. Moreover, Conas can overcome language barriers which exist on construction sites as construction companies usually employ people from all over the world. As the software supports over 30 different languages, it can translate all information accordingly. Therefore, less time needs to be spent to instruct international employees on plans.
Conas, therefore, provides several benefits: First, the user can execute his task with greater accuracy by receiving precise information from the plans. Second, safety is increased because the user can use both hands for the workflow. Third, by leaving comments, the construction process is better documented. Finally, Conas saves time for the construction worker and hence, increases his productivity.

Customer Relationships

Onboarding: Customer onboarding requires the download of the app and the subsequent connection to the earphones. The app comes with learning videos guiding through the first steps, e.g. the upload of the construction plan. The respective file format needs to be provided by the architect, either via CAD or BIM. For firms that are technically not experienced, Conas offers an implementation service. It includes contacting the architect of the respective project and the upload of the data for the customer. To build strong relationships with lead customers, key accounts are set up and personal assistance is provided during the first phase of the respective project. For example, on-site training for construction workers is provided.

Project support: Throughout projects, the combination of software, hardware, and interaction with the customer can lead to technical problems. In this case, the app provides a catalog on frequently emerging questions and challenges. If the worker cannot solve the problem himself, support service is available and reachable through the app. In emergency cases, Conas provides on-site support. This service is available to lead customers only. For feedback and product reviews, the Conas app itself provides an elaborate evaluation tool to directly capture the opinions of construction workers and improve the service afterward.

Channels

Direct channels: Conas markets its product on a B2B basis. The challenge is to convince the representatives of construction firms that are possibly not involved in on-site work. To acquire these firms as customers and to get the product's value proposition across, a direct approach is chosen. Conas' direct sales strategy includes direct mailing and company visits. Besides, to present the product to a larger audience, traditional media, and press, such as trade journals, help to create first touchpoints. Also, construction fairs offer great opportunities for potential customers to test the product.

Indirect channels: The second way to approach customers is via project owners or project development firms. These firms are the main actors for the tendering process and influence the processes on a construction site significantly. Another indirect channel is the construction workers, who have the interest to use Conas as it makes their work easier.
The Conas application is available at all major app stores and provides a demo for testing the functionalities. The optional add-on hardware can be ordered online and is delivered via mail and package service.

Key Resources

Human capital: Being a software company, skilled architects, designers, and software developers are key to Conas' success. In addition to this, experts in the application domain and their knowledge from the industry is important to create a product of high utility for critical construction situations. As Conas relies on many business partners and close customer relationships, employees with strong networking skills are required.

Design-to-speech software and data: The value to the customer is brought by the design-to-speech software which is developed in-house. Our algorithms ensure that it recognizes various CAD and BIM models accurately. The cloud will collect a massive amount of data on construction plans and input from construction workers. This data is crucial to develop custom-fit solutions further.

Additional software interfaces: The design-to-speech software is enriched with additional services of external providers. Therefore, the business partners providing APIs are key resources of Conas. For example, translation services address language barriers within the industry. Also, speech-to-text and text conversion services enable the communication between the worker and the software in the first place. By leaving comments, a worker can call attention to differences between plan and reality or other important notes. The status of an assigned task is documented and can be supervised.
Hardware: The hardware interface between the software and the construction worker consists of high-quality earphones equipped with a microphone. Offering a compatible physical component accounting for the special environment of a construction site creates more value for the customers of Conas. The product needs to be designed robustly and with a noise-cancellation feature.

Key Activities

Conas assists construction workers with design-to-speech services available via earphones. To establish these functionalities, Conas focuses on four key activities:

Development and maintenance of design-to-speech software and interfaces: The design-to-speech service is Conas'

core feature. Hence, the development is concerned with the translation of CAD and BIM models into audio easily understandable by humans. First, it involves establishing access to all relevant data formats for training and testing. Second, putting this information into speech requires the system to understand the semantics of the CAD/BIM model as well as the semantics of documentation and comments given to certain objects. As a third step, the generated text needs to be transformed into speech by a third-party service provider. The front-end realization of Conas includes a smartphone application for construction workers and the cloud to upload models and plans which contain all data that is accessible via the speech assistant.

Acquisition of software service providers and development of APIs: In addition to creating the Conas software, APIs to external service providers need to be set up. Therefore, an essential part of the business model is the acquisition of reliable partners offering their service for the users of Conas. APIs for BIM and CAD software is necessary to read out plans for information such as measures, materials, and locations. Additionally, APIs for services such as language translation, speech-to-text, and text conversion is required.

Customer acquisition and development of relationships: Entering a broad market with a new product pose challenges for communicating its value proposition to the customer. Therefore, acquiring relevant customers and ensuring their loyalty is decisive for market entry and long-term success. This starts with the development phase by involving construction firms throughout the realization of the product. Marketing and sales efforts are prominent activities, especially during the product launch phase. In the long run, those efforts not only need to be maintained but also improved.

Revenue Streams

Conas' revenues are generated from both one-time setup revenue per project and recurring revenues per customer. To offer the product to a wide range of different construction firms, Conas combines a subscription model with a one-time fee for the first setup.

Setup fee: Construction companies pay an initial setup fee dependent on the complexity and size of the underlying construction project. This fee covers the operational assistance.

Subscription model: Conas' primary revenue streams are subscription fees to get access to the design-to-speech service via a mobile application. This fee depends on the number of accounts required, which reflects the number of construction workers on-site. The payment system is based on a monthly subscription fee to account for short-term projects. This way, entry barriers are kept low for new customers of different sizes. For example, this pricing model allows for flexibility during seasons of less construction activity.

Hardware component: An additional revenue stream is created by the sale of the hardware component. Earphones equipped with a microphone and noise-canceling feature are bought in bulk and sold to the customer. As the hardware is highly compatible with the software product and features noise cancellation, it improves the performance of Conas significantly in the noisy and vibrating environment on construction sites. Customers are charged once for the component. To attract more customers during the time of market entry, the hardware is also available on a rental basis.

Individual contracts: In case of high usage volume or long-term projects, contracts are negotiated on an individual basis. This procedure comes along with benefits for the customer including discounts, free hardware, or even a tailored solution. For Conas, these lead customers strengthen Conas' financial position and possibly provide valuable knowledge for the product's further development.

Key Partners

Putting Conas into practice, there are two groups of key partners required. The first group includes partnerships that help to develop the technology and to offer additional hardware.

Of similar importance, however, are partners with expert knowledge that share their experience and test the prototype. This second group includes, for example, project developers and architects, that can also create touchpoints with the intended customer segments.

Software and API providers: The service delivered by Conas is supported and complemented by external service providers. These partners are crucial to realizing major and minor features such as reading BIM and CAD data files, translating languages and speech-to-text processing. Using the services provided by these partners allows Conas to focus on its core activities and enter the market more quickly without sacrificing any quality requirements of the product.

Architects and construction firms: To develop and validate the design-to-speech service, industry knowledge is required. Experienced architects in CAD and BIM modeling and data from existing models can provide valuable insight into early-stage software development. The strong connection to the industry enables Conas to create a product that meets the customer's needs and guarantees a high-quality standard.

Project owners and project developers: These partners accompany a construction project from the beginning to the very end. Hence, they not only possess valuable knowledge about the industry but also maintain a network of potential customers. Winning project owners and project developers as partners is a promising distribution channel, not least because of their influence in setting standards on the construction site.

Hardware supplier: Conas focuses on a high-quality software product. However, its performance and user experience are strongly dependent on hardware quality. Therefore, the right partner who can deliver the required quality for the production of earphones and microphones is key. A strong partnership with its hardware provider will allow Conas to influence some of the design and functionality decisions of the manufacturer as well as receive favorable prices. This enables Conas to offer superior hardware at a highly competitive price.

Customer Segments

General contractors: General contractors normally offer all

construction works from excavation to the turnkey handover and are targeted for two reasons: first, these firms are concerned with a wide range of construction tasks and can use Conas to assist their workers in performing this variety of tasks. Second, subcontracting is a usual practice in this industry. However, the general contractor is still responsible for the project and is tasked with coordination and process monitoring. Thus, the firms can advise or require their subcontractors to use Conas for faster processes and documentation during construction. This way, Conas realizes multiplier effects.

Subcontractors and specialists: The other customer segment consists of smaller companies which are often more specialized and employ fewer workers. Two implications arise for these companies: first, workers do not execute standard tasks and often require special instructions. Second, if only a few workers of a company work on-site, it brings about greater responsibility for the individual. If supervisors or other co-working partners are not available, the worker can make use of the on-site assistance by Conas to fulfill their tasks flawlessly.

Construction workers: Construction workers are indirect customers. Their employers pay for the system, but the workers are the people benefiting directly from it. Conas avoids extra work for the construction workers as they don't need to

search for the supervisors or the paper plan in case of a problem. Instead, Conas supports them in real-time giving them ad-hoc feedback during the whole construction process.

Cost Structure

Initial investments: As with many software products, the initial development of the software requires high upfront investment. To create a viable product, qualified technicians and software developers are required. Further, specialists for CAD and BIM plans consult the technical implementation in how information should be derived from construction plans. The algorithm must be trained to reliably interpret and convert the data into audio information. Furthermore, the acquisition of business partners such as the supplier for earphones is a prerequisite for a hardware offering. Additionally, the use of third-party APIs and software development kits (SDKs) in the software reading out CAD and BIM files, as well as location and translation services, is also a key cost driver. Conas also requires legal advice to clarify possible liabilities.

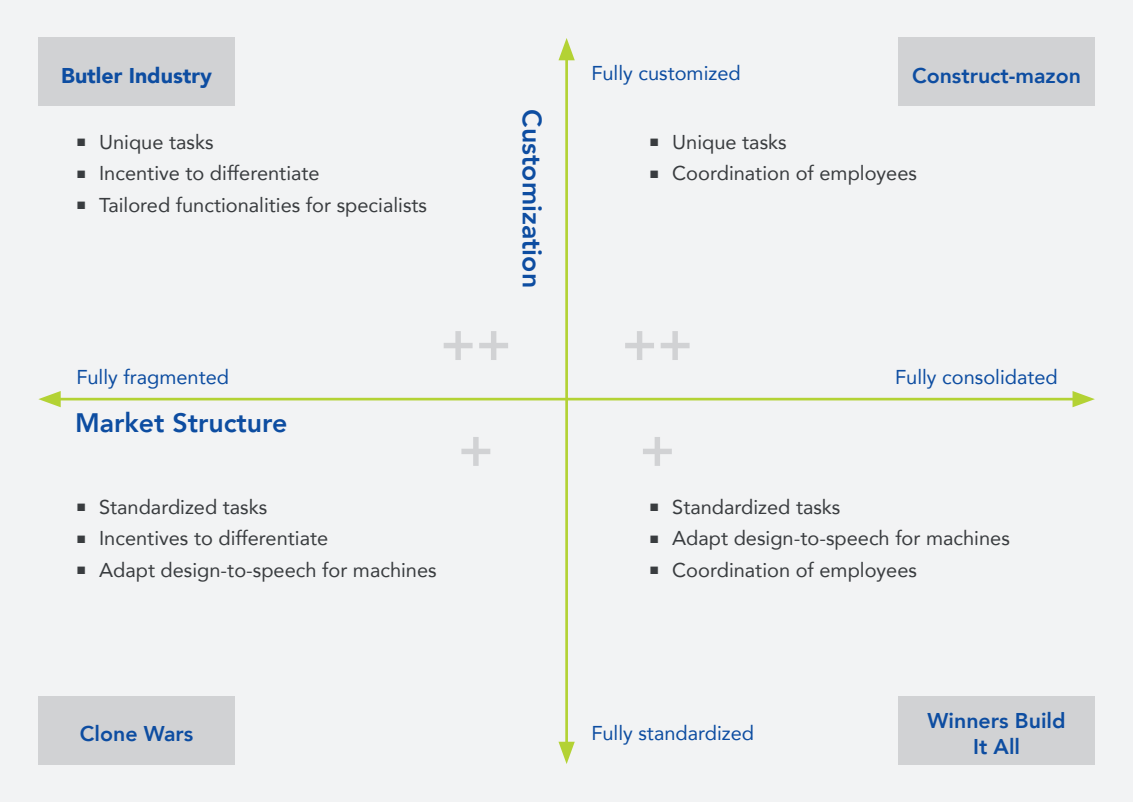
Variable costs: Due to the nature of a B2B market and a large target group, an extensive sales and marketing team including key account management is essential. Marketing experts are tasked to build awareness and create a brand image by developing strategies for the product's public presentation, e.g. at construction fairs. For implementation and further customer requests, Conas maintains a call center which incurs further costs.

Fixed costs: State-of-the-art software products require continuous improvement and technical innovations in. Therefore, a fixed cost segment includes the maintenance of the software product and R&D investments. The main asset of Conas is a high-quality product that enables fast data transfer without interruption. Thus, an appropriate IT infrastructure and user-friendly interface is key to long-term customer satisfaction. In general, a sufficient operational infrastructure includes office space and further work equipment. Lastly, capital costs are not negligible due to high upfront investments.

Scenario Fit:

Butler Industry: In a fully-customized world, construction projects are highly individual which results in time-consuming tasks on-site. A highly fragmented market consists of many small companies. Combining both worlds makes it very likely that companies tend to specialize due to the small number of employees and individual requests from customers. Conas provides the highest value in this scenario due to the following reasons: Individual requests by customers result in many unique tasks for construction workers and almost no standards exist. Hence, audio assistance is extremely valuable for construction workers since every plan is entirely different. On top of that, construction companies are striving to gain market power which requires a larger number of employees. Additional support for workers such as Conas can differentiate a company from its competitors when it comes to recruiting.

Construct-mazon: Exchanging the fragmented market with a consolidated market results in a smaller number of construction companies with a larger size each (up to a monopolist that employs every worker). Hence, the need for companies to differentiate themselves from others decreases. Since customization remains on a high level though, Conas is still a good fit for the market. To increase the attractiveness of Conas in this scenario, coordination of workers could add value for customers. For instance, a conversation with Conas about a measure in a specific room indicates that this worker executed a task in this room. In this way, the construction company can have a better overview of how the workers are



allocated on the construction site and which tasks they currently face.

Winners Build It All: As opposed to a fully customized world, a fully-standardized world results in very similar construction projects and tasks. Hence, more standards are established and known to construction workers. This decreases the value of Conas to a medium market fit. Nevertheless, this scenario is still a medium fit due to possible adjustments such as the coordination of employees. As standardization increases the usability of automated machines and robots on the construction site, the design-to-speech technology can be adapted to translate digital plans such that machines understand them properly. New building techniques like this can create an advantage over competitors which increases the market share of one player in the market.

Clone Wars: In a fully fragmented and standardized world, companies need to differentiate themselves more than ever from competitors. In comparison to the 'Butler Industry', companies tend to specialize less, since more standardization is demanded on the market. Hence, products like Conas can increase the attractiveness of a company on the job market, which is a general goal of all construction companies in this scenario. Just as in the 'Winner builds it all' scenario, the understanding of plan details like measures and materials can increase the usability of automated machines and robots. Since competition in the construction market is higher in a fragmented scenario, the use of robots can be a critical factor when it comes to gaining market power. Hence, we can increase the value of Conas by additionally offering a translation feature 'design-to-machine' which is similar to 'design-to-speech'.

Challenges:

- The solution heavily relies on sufficient internet connection and realizes its full potential with a strong GPS signal. Areas where both are weak pose a challenge to the product
- Conas has to deal with the dependency on external partners and their services' performance
- An extensive testing phase is required to ensure flexibility and accuracy for various architectural plans
- Construction workers might be skeptical towards digital solutions. This has to be overcome to establish Conas as a standard solution for productivity increases on-site

Outlook:

The speed of technology development and its consequences in the past emphasizes how important it is to offer a state-of-the-art product. Therefore, Conas will mature over time. The technology outlined hints to the huge potential of additional features and functionalities. Parallel to enabling exact GPS tracking inside of buildings in the future, the audio assistance can be expanded to information on due dates, responsible parties, as well as instructions on tools, materials, and working processes. The increasing openness of construction firms towards digitized solutions will foster this development. However, the construction industry is not the only industry dealing with complex plans. The design-to-speech software might be potentially tailored to the needs of other industries to make processes more efficient or even help disabled people in joining jobs that previously relied on visualization. Therefore, the product might also overcome the boundaries of just one industry.

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CRAIDAR

Enabling Connectivity and Progress Tracking on the Construction Site

In the past 50 years, many industries have seen incredible increases in productivity and efficiency. These industries have especially profited from the automation of processes, enabled through embracing new technologies. Contrarily, the construction industry has not seen much innovation in the recent past. As a result, it is one of the few industries that has not improved its processes significantly. The construction industry shows immense potential for increases in efficiency through the use of new technologies, especially the adaptation of connected IoT-devices. However, most useful applications realizing this potential require a specific form of internet connection, which is in most cases not sufficiently available on construction sites at the moment.

Craidar helps to solve this issue for large and medium-sized construction sites by providing two modules: a Wifi-Module delivering a reliable and fast internet connection to construction sites and a LIDAR-Module enabling the tracking of the construction of the building shell. If a crane is available on the construction site, the Wifi-Module will be mounted on top of the crane. As soon as there is no crane available anymore, the module should be attached to a central and relatively high point on the construction site. Depending on the location and possibilities for providing data in the particular area of the construction site, there are three ways to supply the module: Landline, cellular networks, and satellites. For an optimal connection, especially on large construction sites, the Wifi-Module can be reinforced through amplifiers. These allow the use of IoT-devices, as well as increased automation on construction sites.

The LIDAR-Module will be installed in the crane boom on the trolley, with which it will move along. After the disassembly of the crane, the LIDAR-sensor provides no additional benefit, since the shell of the building is finished and most changes are now done inside the building. LIDAR-sensors and cameras in the module generate a point-cloud and a 3D-model of the construction site. Craidar will provide an API for manufacturers of BIM- and project-management-software so that the models can be used for automated comparisons of the BIM model with the constructed building shell, as well as automated tracking of the adherence to the planned building process. Also, detection of workers and building material could be improved when utilizing automated crane steering, leveraging the data generated by the sensors.

Business Model

Key Partners

- Suppliers and device manufacturer
- Telecommunications providers
- Manufacturers of construction machines
- Providers of BIM- and project-management-software

Key Activities

- Continuous product development and improvement
- Building and maintaining partner network
- Training of employees for montage and usage

Key Resources

- Technical hardware know-how
- Patents on the LIDAR-module
- Sales network (manufacturers of IoT-devices and crane manufacturers)

Value Proposition

- Wifi: Ensuring connectivity on the construction site and large data packages for multiple IoT-devices
- Laying the groundwork for an exponential increase of IoT-devices on construction sites
- Efficiency gains and cost savings by enabling usage of connectivity-based services
- LIDAR: Accurate assessment of building progress
- Transparency about the status quo of the building process
- Ability to track progress and tailor measures accordingly
- 3D-Model of the construction site and data of the building process for external use (API)

Customer Relationships

- Acquisition (personal assistance/key account manager)
- Leveraging partner companies' customers
- Trusted, long-term, personal partnership
- Continuous advice, service, and support

Channels

- Direct mail and sales
- Partner network and recommendations (leveraging manufacturers of IoT-devices)
- Referral program through a network of construction companies
- Trade fairs and industry summits

Customer Segments

- Medium and large construction companies
- Crane manufacturers

Cost Structure

Fixed Cost

- Development and maintenance of software
- Maintenance of IT-infrastructure
- Employees for sale and support

Variable Cost

- Production costs
- Revenue share for sales partners
- Customer support/training

Revenue Streams

Non-recurring Revenue

- Wifi-device and software
- Additional Wifi-modules/amplifiers
- LIDAR-device and software

Recurring Revenue

- Revenue share for data pay per use/flat rate for data usage from telecommunications providers
- Income from customer support

Value Proposition

Laying the groundwork for the exponentially increasing use of IoT-devices: By using the Craidar system, in combination with construction-specific Wifi-amplifiers, it allows for a high throughput of data and enables the proper use of IoT-based machinery. Here, the system serves purely as a hardware component. The Wifi-Module also enables the usage of the LIDAR-Module described below.

Efficiency gains and cost savings by enabling usage of connectivity-based services: The use of IoT-devices on the construction site is made possible by the Craidar system, it enhances further effectivity growth, more transparency, time- and therefore cost-savings.

Transparency about the status of the building process: By generating point clouds using LIDAR-sensors and cameras at the same time to ensure good cross-sensor calibration, the system generates precise overviews of the construction site and can translate it into a 3D-model of the building.

Ability to track progress and tailor measures accordingly: The data generated can be used to assess the building progress. Therefore, project planners keep an overview of the status of the construction site. Measures can be adjusted accordingly, and the project gains flexibility.

3D-Model of the construction site and data of the building process for external use (API): The data generated can easily be used by other services using an open application programming interface (API) for data exchange. This enables other software providers (such as BIM and project management tools) to feed the Craidar data into their models.

Customer Relationships

Acquisition (personal assistance/key account manager): Interviews with construction companies showed that the industry highly depends on key account managers of the large machinery manufacturers when it comes to machine purchases. Offering discounts, warranties and especially high service levels, they manage to sell machines very efficiently. Often, they have a very strong customer relationship. Craidar, therefore, has to aim for an even closer customer relationship than the industry standard. Personal contact, a large field-sales team as well as a strong collaboration between sales, key account management and (spare-part) after-sales are the key elements to reach this goal.

Trusted, long-term, personal partnership: The Craidar team should actively aim for an excelling, one-stop service level where any need of a customer can be solved by calling his or her assigned key account manager. To achieve this, service task forces consisting of members of all potentially involved departments have to be set up. The key account managers do not serve as sales agents here, like in other business cases, but more as coordinators of all resources Craidar provides. The sales team should be a separate union which generates leads (inside-sales), pitches the product and closes first-time deals only (field-sales and outside sales). A state-of-the-art customer relationship management and sales tool such as Salesforce will help to achieve this goal, allowing the key account managers to also include live usage-data from the system to monitor customers.

Continuous advice, service, and support: By incorporating usage-tracking features into all connected modules, Craidar will be able to detect increased and decreased, and later even right and wrong usage of the system. Leveraging this data, customers can be coached on how to perfectly utilize their system to increase efficiency as well as to prevent breakdowns in the long-run.

Channels

The construction industry is a highly conservative and fragmented industry, dominated by family businesses. Construction companies can be easily reached through direct (postal) mail to approach cold contacts and inform about our product. Provided these companies have an interest in our product, the sales team can then go into direct contact and start negotiations. Also, as complex hardware sales require a lot of trust on the customer site (reliability, support in case of maintenance problems and more), direct sales are an appropriate B2B channel. Craidar can leverage partnerships with industry associations and build the groundwork for a wide-spanned partner and customer network.
While construction companies are always competing for projects, there still is a strong network between these firms. Craidar will incentivize satisfied customers to refer products. Possible incentivizes are as aforementioned free data packages, discounts on existing orders or via revenue shares.
Manufacturers of cranes, construction machines and IoT-devices as well as providers of construction-related software systems comprise the ideal partner network. These companies are perfect candidates to become sales partners. Craidar would provide a revenue share to advertise and recommend the hardware solution.
For tool manufacturers, trade fairs are still very important to network with other companies and to successfully position themselves as a premium brand. Being present at these tool fairs will make construction companies and tool manufacturers pay attention to our product, as well as help with building connections to potential customers and partners.
Using the strong cross-company ties of the industry, Craidar plans to leverage word-of-mouth advertisement by setting up a product referral program, which incentivizes happy customers to either sign new customers or to actively advertise Craidar via their channels. Companies could be incentivized via free data packages, discounts on existing orders or revenue shares.

Key Resources

One of the most crucial resources for Craidar is the technical hardware know-how. The combination and calibration of different sensor types are critical to guarantee a high level of data accuracy. While the hardware itself is not complicated and easy to replicate, Craidar relies on the secure and easy attachment to cranes, as well as software developers to develop the interfaces for communication. Craidar has to tailor the product to work in all use-cases on differently sized construction sites across the globe. It is important to process and prepare the data for further usage. Therefore, technical know-how is key for market success.

The most important resource of Craidar is intellectual property. While the Wifi-Module cannot be patented, Craidar relies on patents for the LIDAR-Module. Filing patents on the LIDAR-Module allow a competitive advantage and restrict the competition severely in relevant core markets such as Germany. Patents on the LIDAR-Module will ensure long lasting profits from the developed system.

To sell the Craidar-System, a sales network of manufacturers of IoT-devices, construction machines and cranes is highly important. A partner network containing both IoT-tool-providers with a long history in construction and strong sales networks is key to promote the Wifi-Module. BIM- and project-management-software-providers can be interesting partners to promote the use of the LIDAR-Module.

Key Activities

Continuous product development and improvement: The LIDAR-Module can be built similar to how it is currently used in the automotive industry. Correct calibration of the Wifi-Module to provide a reliable connection will require a lot of effort, but the technology already exists. Since the technology for both modules is already available, developing the initial system becomes feasible. To beat arising competition, Craidar needs to keep this technological advance and invest a lot of effort into R&D. Craidar also needs to ensure a consistently high product quality to ensure customer satisfaction, making regular bug fixes and updates necessary. Another important part of product development is the maintenance of the API to ensure a functioning interface between the LIDAR-module and the connected devices.

Building and maintaining partner network: Partners are construction-related manufacturers of IoT-devices, BIM- and project-management-software providers, as well as crane manufacturers who want to offer additional services to their customers. These groups share an interest in a more connected and better-steered construction site, making them the perfect partners for a revenue-share sales partner model. It will be necessary to incentivize crane manufacturers to offer our module with the sale of a crane. In the long run, Craidar will have to negotiate contracts and conditions that enable software companies to use the results of the LIDAR-module and to have a large number of software companies using the results from the LIDAR-Module.

Training of employees for montage and usage: To use the Craidar-System properly, construction companies need to know to properly use the system. After the first purchase, companies will be assigned a dedicated Craidar sales person instructing employees on how and where to mount the system in the form of a workshop of up to 3 days.

Revenue Streams

Non-recurring Revenue

Craidar's major revenue stream is based on hardware sales, with the Wifi-Module as the primary product. Clients can buy and lease the Wifi-Module as the basic unit. For complex building sites, the unit comes with software providing an optimal strategy for setting up the module together with additional amplifiers. The additional amplifiers can be bought or leased. They will be provided through an external partner with Craidar adjusting these for the use on construction sites to ensure an optimal connectivity coverage. The combined forces of the Wifi-Module and advanced amplifying systems ensures a high-quality network.

A second revenue stream will come from selling and leasing the LIDAR-System together with a basic 3D-software, making sense of the data generated so that they can be used by other applications. The LIDAR-System requires the purchase of the WIFI-System. The price of the system depends on the type of crane used and the type of sensors built into the crane. The classical hardware components can be purchased together with cranes to enable more use cases. The earnings are generated by direct sales of the module and will make up

most of the revenues generated.

Recurring Revenue

Craidar will also make revenue from the consumed data. In cooperation with existing telecommunication providers, Craidar allows choosing between different offerings of selected data packages or flats suited to the needs of construction sites. Craidar will negotiate the terms and conditions as part of a frame agreement and sell the access to the target group to selected telecommunication providers.

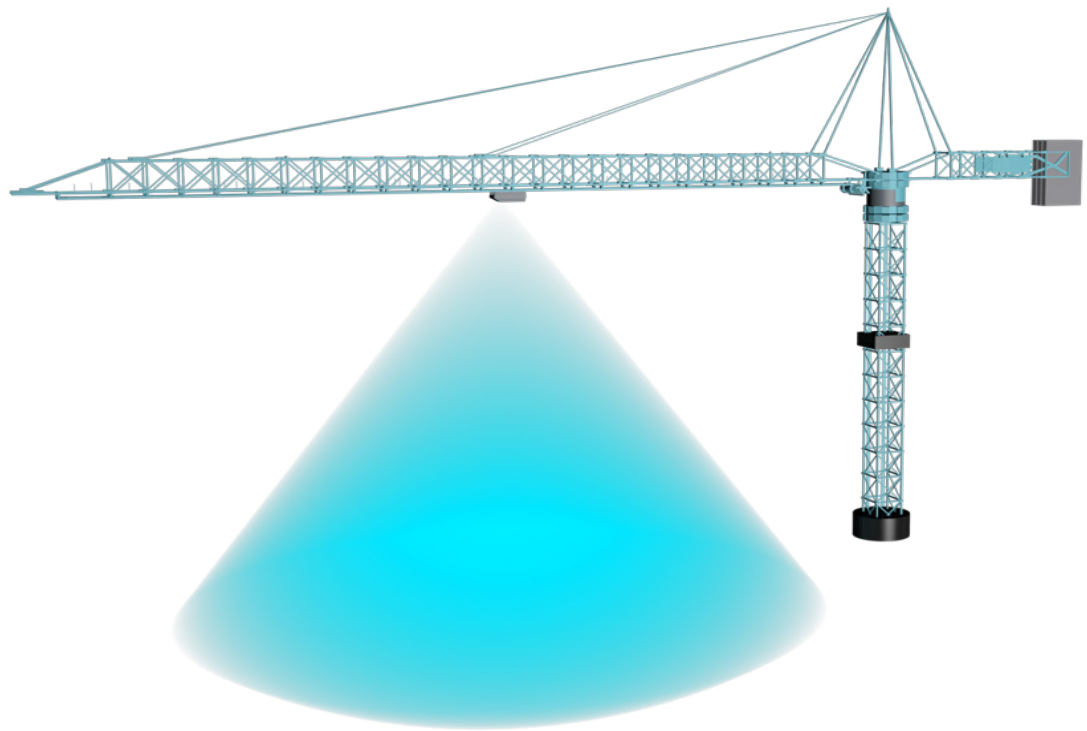
Lastly, Craidar derives revenue streams from services around the system. This includes but is not limited to added revenues for special customer services, such as premium 24-hour and on-site support and additional help with the implementation of the system that diverges from the original setup services that come with the purchase.

Key Partners

Suppliers and device manufacturers: Craidar will provide clients with a Wifi-Module that supplies the construction site with an internet connection. This unit will be attached to cranes and other elevated points on construction sites. For the Wifi-Module, Craidar will acquire the required antennas, cables, satellite dishes, as well as other hardware components from third-party providers. There is a large number of suppliers available for these components. For the LIDAR-Module, Craidar will produce weather- and a wind-proof case containing all LIDAR-Sensors and cameras. The LIDAR-modules are offered in different types according to the height of the crane and its technical specifications.

Telecommunications providers: For the Wifi-Module to be functional, telco providers are required to provide an internet connection for the construction site. There are three major ways to supply the Wifi-Module with data. For construction sites with an already developed infrastructure, a landline is the optimal solution. For remote construction sites with no landline connection, cellular-networks will be used. If no cellular networks are available, satellite-connection serves as the last option.

Manufacturers of construction machines and IoT-devices: Increased availability of IoT-devices for the construction site will raise usefulness and profitability of the Wifi-Module for clients. Since there is currently only a small number of these devices available, Craidar will partner with manufacturers of construction machines to promote machines using IoT-technologies to enable the tracking of usage, predictive maintenance, and other use cases. These partnerships will in return also promote the Craidar-System.



Project management software providers: To fully utilize the LIDAR-Module, Craidar builds on partners who make use of the additional collected data. BIM- and project-management-software-providers are ideal partners, as they can use the collected data to evaluate the process, compare the actual progress to the plan of the project and use the data to display current and expected delays. The data generated by the system is given out to them for free via an API (application programming interface) to incentivize software providers to promote Craidar's hardware as a technical enabler for their services.

Customer Segments

Medium-sized and large construction companies: Construction companies can buy the Craidar-System and install it in their existing cranes or buy it together with cranes from partner companies. Depending on the type of construction

site as well as the type of crane, different versions of the system are offered. Customers pre-configure their devices targeted to their needs concerning sensor accuracy and size of the construction size. The systems, later on, can be modified according to up- or downgrade wishes. Also, additional components such as Wifi-amplifiers can be purchased with the system. Since the system is better suited for complex building surroundings, large and mid-sized construction companies are the key target group.

Crane manufacturers: Crane manufacturers can be sales partners as well as customer, depending on the intensity of collaboration chosen. By using the patented Craidar-System in their cranes, they can keep the technological edge without having to invest too much in sensor R&D themselves. The Craidar-System could be an interesting cross- and after-sales opportunity for crane manufacturers, which makes them perfectly suited B2B resale partners.

Cost Structure

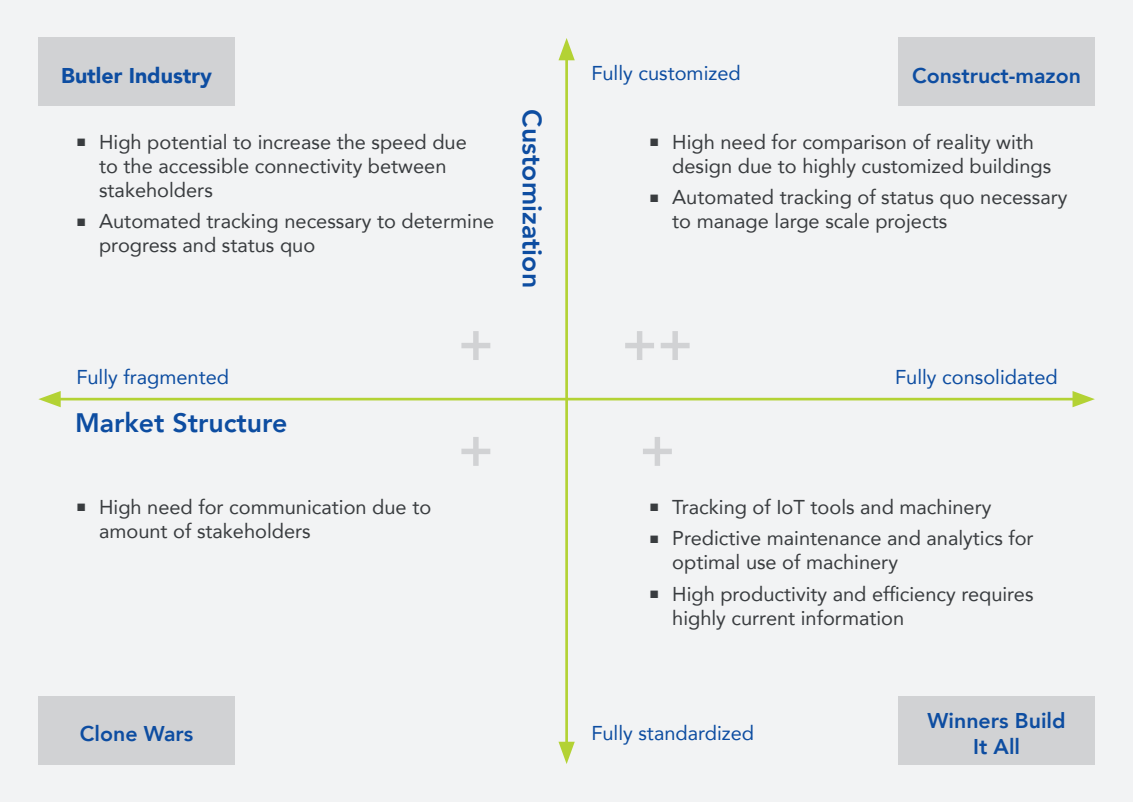
Fixed Costs: The largest part of the fixed costs consists of developing and maintaining the system. Development of the original system is relatively simple since the Craidar-System builds on already existing technology. To stay competitive, Craidar will have to make large investments into R&D for continuous improvement of its system. For processing the data generated by the LIDAR-Module, maintenance of IT-infrastructure will also play an important part. Personnel costs will also be an important part of the fixed costs. Employees are responsible for maintaining the infrastructure, develop hardware and software, as well as marketing, sales, and 24/7 customer support, which will focus on building relationships with construction companies and manufacturers of construction machines.

Variable Costs: The largest part of the variable costs consists of material costs, such as sensors. Depending on the unit bought, the number of components, as well as the costs for the components varies. Purchasing of material will not be outsourced, because, in order to persist on the market, a high and consistent quality needs to be offered to clients. Manufacturing of the final product will be another part of the variable costs; this will be outsourced to a third party. Telco-providers will have to be paid a revenue share for the data used by customers.

Scenario Fit:

Butler Industry: In this scenario, the domination of customized houses within a fragmented market will lead to the need for a high speed of building houses. This will be hindered by the problems of communication between the high number of different stakeholders. In this case, Craidar has a good chance to flourish. It has the potential to increase the speed due to the accessible connectivity between the stakeholders. The automated tracking of the progress is necessary to determine the progress and the status quo.

Construct-mazon: In this world, the construction industry is fully centralized, and houses are fully customized. For the large construction companies to function properly, they need to have well-organized structures and processes. Especially in the construction of fully customized houses, the delay is common, and companies need always to know the status of a project to plan. Due to the highly customized designs, companies also need an easy way to track if the building is constructed according to the plan. Craidar allows companies to track the process while erecting the shell of a building and use this knowledge to manage workers and delivery of material accordingly. It allows these companies to automate the



monitoring of the alignment of plan and reality during the construction of the outer shell.

Winners Build It All: In this scenario, the houses are fully standardized. Therefore, the construction process needs to be highly efficient. This requires companies to exactly know the status of the construction process and when to order new materials. This new transparency enables partial automatization of the delivery process. The LIDAR-Module will support the efficiency aspects of this world by providing a comprehensive picture of the status quo on the construction site. Due to the high degree of automation, the building process will include a lot of IoT devices and machinery. The WiFi-module will be the enabler for automation on construction sites. Other aspects enabled through the modules will be predictive maintenance and analytics for the optimal use of machinery.

Clone Wars: In this scenario, the world is fully standardized, but also fully fragmented. This leads to a high need for communication due to a large number of stakeholders. Therefore, especially communication platforms are needed. The usage of these will be possible through the Wifi-module of Craidar on construction cranes and unfinished buildings. Especially with a high number of parties, efficient processes require highly current information. Because of the high standardization, machinery is completely automated. The Wife- and the LIDAR-module meet these requirements. Regarding cooperation on the construction site, the modules could be used by different companies on site. The cost for these can be shared, keeping the price for the individual small company low.

Challenges:

- Adoption of LIDAR-system and IoT-devices by the construction industry
- The setting of industry standards
- Strong competition from manufacturers of construction machinery and IoT-devices
- Proper mounting of the system by construction employees
- Creation of partnerships with telco-companies as well as manufacturers of BIM- and project management-software

Outlook:

Craidar is entering a very promising market: It is predicted that global spending on IoT across markets will reach $1.29 trillion [1]. This development will certainly also spread to the construction industry. Many applications on construction sites will need a fast and especially a reliable internet connection. This need includes, but is not limited to, use cases regarding the remote operation, supply replenishes, construction tools and equipment tracking, equipment servicing, and repair. Additional software for BIM and project management can profit from a reliable internet connection on construction sites.
The LIDAR-Module's original use case is the remote and automated tracking of the progress on the construction site. In the future, Craidar will develop further use cases for the LIDAR-Module, such as automated crane steering and load dropping. Craidar will focus on improving automated crane steering software, as well as software improving safety on construction sites. Depending on the scope of the Craidar system chosen, the system uses a camera and LIDAR-sensors to assess the ground of the construction site, allowing to drop placing material at a suitable place.
Craidar's success depends strongly on the adaptation of IoT-devices on construction sites and the cooperation of manufacturers of BIM- and project-management-software. While 5G might be sufficient for BIM- and project-management-software, a high number of IoT-applications requires a more reliable and cheaper connection. Craidar has a high potential to pave the way for the digitization of the construction industry and increase its efficiency.

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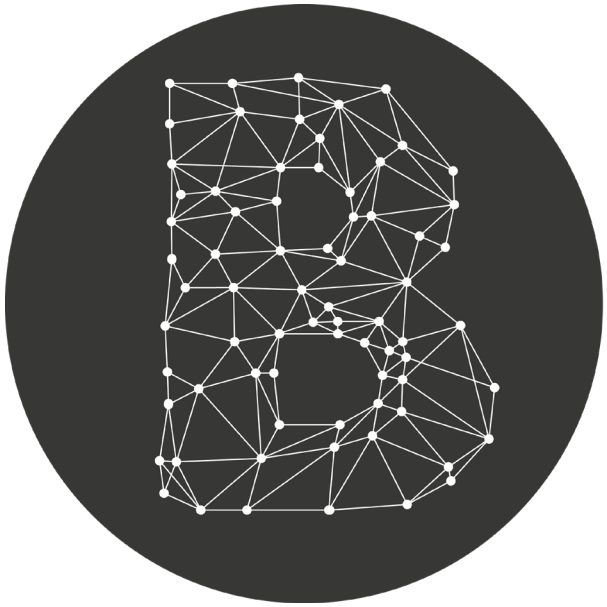


BIM
LENS

BIMLENS

Making BIM More Accessible On-Site with AR

One of the key problems heavily affecting construction projects is a deviation from original designs. At a higher level, such deviations happen due to a lack of knowledge about the design on the contractor's side, and at a lower level due to mistakes by the workers. Unskilled workers are prone to make errors in building complicated construction structures, fitting of various appliances such as positioning pipes and wires in a wall, and in installing proprietary equipment from third-party vendors. Often these mistakes are detected too late, due to insufficient monitoring and documentation of what is built. BIM is a highly useful technology that has always had the potential to alleviate many pain points of the construction industry. However, the construction industry has been slow in adopting the technology, and consequently, BIM has not yet been fully utilized as an on-site collaboration tool.

With BIMLENS we make BIM accessible on-site to help workers in executing construction tasks and to allow documentation of design deviations. BIMLENS uses Augmented Reality (AR) techniques to guide workers in properly installing complex components.

BIMLENS comes in two forms: First, a software that can be installed on regular Android and iOS smartphones, and second, as specialized AR goggles. The core feature is centered around guiding the worker to perform a certain task by showing instructions, virtually overlaid on the construction entity. For instance, if a worker is installing water pipes in a wall, BIMLENS will guide her by showing the exact position and orientation of the pipes in the wall. BIMLENS also makes the BIM model available on every worker's smartphone. Therefore, in addition to AR, the instructions can be embedded inside the model so that the worker can see the model dynamically changing on her smartphone as per the construction requirement which will allow the worker to get a better idea of fitting a particular component. Since it is not always possible to follow the original design, and some components may be built differently from the design, as a secondary feature, BIMLENS allows documenting these changes inside the model for that specific component.

Business Model

Key Partners

- AR hardware manufacturer
- BIM software companies
- Appliance supplier (3D models and installation guides)
- Research institutions

Key Activities

- Software/platform development
- R&D in AR
- BIM integration
- Customer onboarding

Key Resources

- Software, IP, patents
- Developer platform
- Talent

Value Proposition

- Bridge gap between BIM usage in design process and on-site to increase BIM compliance
- Mitigate lack of knowledge of on-site workers caused by worker attrition and subcontracting
- Reduce construction flaws that lead to high rework costs if identified late
- Update BIM if a task cannot be performed exactly as planned

Customer Relationships

- Long-term and close relationship to drive change management
- Co-creation with early customers
- Strong focus on onboarding of new customers

Channels

- Trade fairs to create partnerships
- Designers as sales partners
- Direct outbound sales
- Referral programs

Customer Segments

- Construction companies which use BIM and lead projects
- Specialized subcontractors with access to BIM

Cost Structure

Fixed Cost

- Platform operations
- Software development
- Frequent updates to ensure integration with BIM software

Variable Cost

- Salespeople and account manager
- Customer support
- IT infrastructure
- Hardware Purchases

Revenue Streams

- Software subscription fees
- Hardware product sales
- Consulting
- Training and workshop sessions
- Sale of individual developed solutions

Value Proposition

By providing detailed instructions on how to perform tasks to construction workers via a non-obtrusive AR interface, BIMLENS is valuable on four dimensions: BIMLENS increases on-site BIM usage, reduces construction flaws, mitigates workers' lack of knowledge, and enables workers to document deviations from the model easily.

Currently, BIM models are used on-site as plotted 2D plans which do not include all the information that can be attached to objects in BIM. Thus, the value of BIM is not realized to its fullest extent on-site. With BIMLENS, workers can directly access the model including all its information. By visualizing BIM details in AR, it is easier to understand, and instructions help to assure that progress is made as intended. As flaws often require expensive rework in later stages of the project, significant cost reductions can be realized and time schedules can be met more easily. Third, on-site workers are often subcontracted, and attrition is high. Thus, knowledge management and education of workers takes time, and no learning curve can be leveraged as workers leave, once they've gained experience. BIMLENS supports workers along the process with specific instructions that help to perform the task. Fourth, workers may sometimes need to intentionally deviate from the model. With BIMLENS, workers can document their work by, e.g. attaching images to the respective objects to enable designers to update the BIM model to necessary deviations. This dramatically increases the value of BIM in late construction stages as well as operations and maintenance.

Customer Relationships

BIMLENS is not a self-service product since BIM is not standardized and custom integrations with different providers are necessary. Thus, customer relationships are rather long-term and personal. Each customer has one single point of contact, a customer success manager, that offers support and helps with problems. The main goal is to retain customers on the monthly subscription once they signed the initial agreement. Increasing revenues by increasing the adoption of existing customers are more promising that trying to generate revenues from new customers only. In the long run, BIMLENS can also be deployed without the need for personal interaction when BIM APIs are well defined, and appliance makers are onboard. At this stage, self-service customers could be monitored and contacted by the customer success managers when a significant upselling potential is identified, or the customer is otherwise likely to churn.

BIMLENS requires training of on-site and off-site managers at any point in time, as the technology is new and understanding the functionality is crucial for them to lead the adoption on-site. Workshops with them lead by BIMLENS consultants are an essential part of the onboarding of new construction companies. After the first onboarding of existing staff, the customer can decide to either have an expert inhouse who onboard new employees or pay for workshops conducted by BIMLENS consultants also at later stages.

Channels

Since the construction industry is traditional and BIMLENS solves many of their issues but is not a solution they are actively looking for, scaled online channels will most probably not be the best option. Especially since customer relationships are long-term and close, sales activities need to be more direct and personal. Trade fairs are an important channel to meet decision makers from the construction industry early on. The fairs allow us to be efficient in the beginning since we can schedule many personal meetings in a short amount of time and get feedback on BIMLENS and establish the first partnerships.

Direct sales are our most important channel in the core customer segment. Most of the interactions will be outbound as creating awareness to drive inbound is expensive in the beginning. Later, PR and print/online advertisements can be leveraged to increase efficiency by generating inbound leads. Events at which decision makers of the construction industry meet will stay an important channel.

Since BIMLENS is implemented by the construction company leading a project and then used by subcontractors collaborating on the project, these subcontractors can make use of BIMLENS without procuring it themselves. Directly selling to subcontractors that lead other projects but have already utilized BIMLENS, is a promising channel as the sales effort to explain the solution is reduced significantly.

Since architects and designers profit from increased BIM compliance and since they are advanced users of BIM, they could act as sales partners of BIMLENS. Using sales partners that already have close customer relationships makes the process more scalable and allows BIMLENS to grow quickly without a large internal sales team.

Key Resources

The main resource is our software with the research conducted in the field of AR combined with our learnings for the BIMLENS user experience. To protect this key resource of intellectual property, we plan to file patents. Also crucial for the long-term success of our company is the talent of our employees. A great work-life balance and office perks should tie our engineers to our company. We set up non-disclosure agreements as well as non-competition contracts to further protect our knowledge.

Key Activities

Our main activity is the development of the software including research in AR. At BIMLENS, we want to not only provide software but rather develop a full platform with a developer community to support network effects. It is crucial to integrate appliance suppliers as well as BIM software providers during the development. BIMLENS syncs the 3D models and tasks with BIM. Further, we plan to co-develop our product with selected construction companies to ensure a great fit to existing problems.

Revenue Streams

The key source of revenue is the monthly usage fees. Customers pay a fee of 159 EUR per user and month for BIMLENS. Also, customers also receive hardware via us to be able to offer them a full solution. We buy the hardware in bulk from the manufacturer, install the BIMLENS software, and ship it to the customer.

Moreover, we offer to consult services to our clients. Our consultants support in the transition to using BIMLENS on the construction site and also offer workshops to train construction workers in using our product. Customer pay for this service per hour and consultant.

Lastly, our customer can request individual and customized solutions. This service is charged depending on the required effort and needs to be negotiated. Customers who have their engineering team, can purchase our SDK and build on top of our platform.

Key Partners

BIMLENS has multiple integrations and requires intense collaboration with stakeholders. First, we partner up with manufacturers to buy AR hardware. This could either be AR glasses like Magic Leap One or Microsoft HoloLens. As a cheaper alternative, BIMLENS can also be used on Android and iOS smartphones which support AR technology.

Further, appliance suppliers are required to provide 3D models and installation guides of their products. These are then integrated with our software. The 3D models are used to virtually display the products through AR. The installation guides are uploaded to our platform and provide the construction worker with step-by-step instructions during the construction process.

To fully integrate with BIM, cooperation with software companies is beneficial. An open BIM software which allows plugins or offers an API is the minimum requirement. We want to foster a developer community early on, by offering online forums, documentation, and a helpdesk.
Lastly, at BIMLENS, we want to cooperate with universities and other research institutions to exchange ideas and research findings in the field of AR.

Customer Segments

BIMLENS is a B2B solution targeted at medium and large construction companies. The customer segments are uniform and value-driven instead of cost-driven:
The core customer segment is large construction companies. With increasing BIM penetration, due to regulatory requirements and technological developments, this customer segment looks for smart ways to leverage BIM for their benefit. This segment leads projects and manages many subcontractors on-site. Thus, they benefit the most from the core value proposition of not having to educate the changing workforce by setting up BIMLENS for their projects and providing subcontractors access to it which might also involve hardware. Also, they manage projects of significant size to have the resources to invest in new technologies. The first subsegment within this broad core segment is early adopters. Companies with young management teams will most probably lead to the adoption of AR technology.

Apart from the core segment, specialized construction companies who might also act as subcontractors can benefit from BIMLENS as well. As they do not lead projects, they depend on getting access to BIM. Furthermore, it depends on their specialization whether BIMLENS is meaningful to them, e.g. demolition companies probably do not need frequent instructions.

Cost Structure

Our cost structure can be split into fixed and variable costs. The major fixed cost is the technical research and software development costs, meaning the salary for the software and AR engineers. As our software is the main resource, we rely on skilled developers who are scarce and require high compensation. Also, regular BIM integration checks and updates of our connections are required as the main BIM software is updated to ensure compliance with new releases. Moreover, the developer platform requires frequent checks and maintenance.
Our variable costs are mainly driven by costs related to customer relations. Key here is the sales team and the customer service team which support our clients when using BIMLENS on site. Smaller variable costs include the IT infrastructure, meaning the fees for cloud computing providers, and the purchase of hardware for our customer.

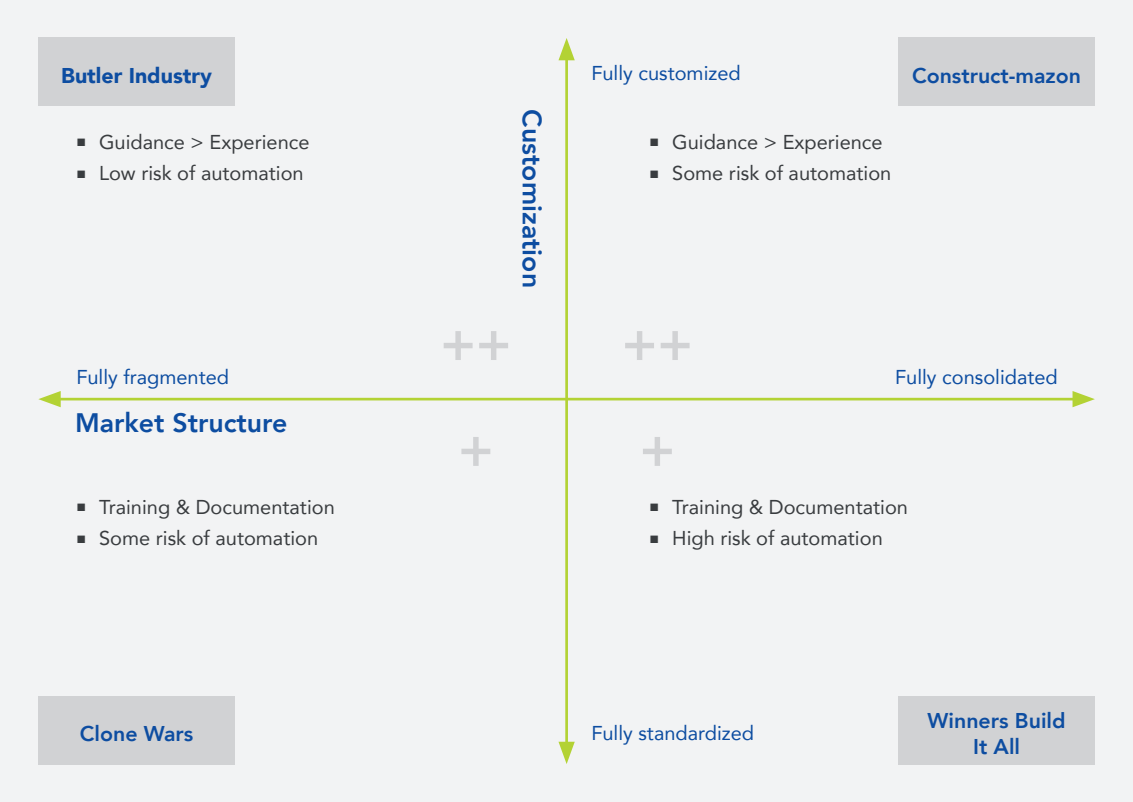
Scenario Fit:

Butler Industry: In a construction industry which adapts to all wishes of the customers and is fragmented to the fullest, the solution provided by BIMLENS is not a luxury, but a necessity. Due to the wide range of appliances that constructors have to install, BIMLENS' product eliminates the need for installers to have extensive experience by providing them with appropriate on-site guidance for each task they do. Since the market is highly fragmented, the investment possibilities of customers are reduced. This means that BIMLENS will need to focus on working with mainstream products which are already owned by the users and implement a 'Software-as-a-Service' (SaaS) model. Since the impact of the platform is so high, appliance suppliers will have a high incentive of integrating with the guidance platform and becoming partners.

Construct-mazon: Featuring a construction industry which is very centralized yet offering products tailored to the needs of each, this scenario helps BIMLENS push technology to the limits with a high-tech company owned devices, acquired by the giants of the industry. This availability of capital increases the risk that more tasks on the construction site will be automated, but, as showcased by present day's state of the automotive industry, enough tasks will be sufficiently complex to require human workers. As in the previous scenario, BIMLENS's main product will be on-site guidance due to the diverse array of products constructors have to interact with. Depending on how the construction companies decide to tackle the development of custom software, BIMLENS might face competition from them or have them as partners in co-creating the product. Finally, another impact of the high centralization will be a reduction in the number of BIM software suites in use by the industry, simplifying integration for BIMLENS

Winners Build It All: A world where all the buildings are standardized, and there are very few players in the construction market is one where work is most efficient. Driven by large amounts of available capital and streamlined designs, automation of the construction sites reaches its peak, with robots performing the repetitive tasks. The jobs for which human workers remain cheaper than robots will also be dominated by repetition, but at a higher level, between individual projects. This implies that on-site guidance, BIMLENS's starting product, becomes irrelevant. To compensate, BIMLENS has to shift its focus to documenting executed work and to assisting new workers in learning the tasks they need to do. In this way, the risk can be mitigated, and the company can take advantage of other aspects of the construction landscape, such as ubiquitous high-tech AR devices and the reduced variety of appliances the software has to integrate with.

Clone Wars: This scenario is characterized by an industry fragmented to the fullest, but in which each actor does work the same way because of standardization. While automation is not a big risk in this case, due to the lacking spending power of the companies, the reduced complexity of the construction site does represent a threat that BIMLENS has to tackle. Since tasks become repetitive, both at the project and day-to-day level, most of the workers' learning on the job is done when they join the workforce and guidance is not required afterward. In this setup, BIMLENS can pivot towards providing the initial training to minimize the onboarding period, and it can further adapt by providing a documenting solution for individual steps of the workers' tasks. On the hardware side, the company should concentrate on mass-market devices, which are owned by the constructors. Together with a SaaS business model, this strongly reduces the need for upfront investments and optimally targets the market.



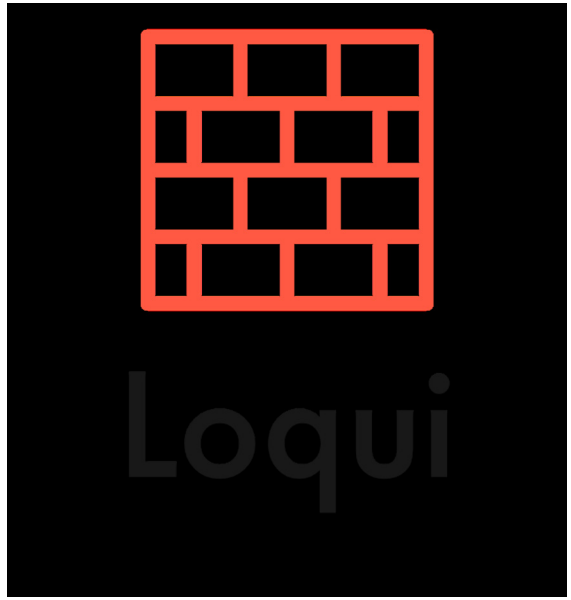
Challenges:

- Technical implementation of such an AR product involves challenges that require considerable R&D
- Lack of incentives may prevent the appliance suppliers from providing instructions for their equipment
- High Hardware costs may prove to be a hindrance for the company, in adopting the solution
- General lack of technical skills in workers may lead to problems in worker on-boarding to this solution
- The fragility of the AR devices may prevent their on-site adoption

Outlook:

Lack of skilled labor is a serious problem for the construction industry. As a result, tools such as BIMLENS that assist workers in doing their tasks effectively are in high demand. BIMLENS uses computer vision to detect the construction entities in the real world which are then mapped to the BIM design as well as the instructions from appliance manufacturers to present the virtual guidelines to the worker. Computer vision, however, is suitable for detecting large and well-defined construction entities, but it may not be the best solution for detecting very small details especially with 2D cameras. In the future, however, AR goggles will be enhanced to incorporate additional sensors that can pair with various appliances for improving the detection of small components. Current smartphones are restricted with their 2D cameras and break easily, so a new, sturdy, smart device can be introduced which supports 3D cameras and additional sensors to aid in detecting objects at construction sites.

Shiv Contractor, Maximilian Deichmann, Christian Spier, Mathis Stolz, Jingchen Wang



LOQUI

Enabling Simple Communication and Task Management on the Construction Site

Often, a sizeable amount of time spent on the construction site is for delegating tasks to construction workers and collecting progress updates. Since these sites could be huge, the time and effort spent in physically meeting a supervisor or worker usually accounts for almost a quarter of the working day. In addition to this, the construction companies face several complaints from residents and office workers situated in the vicinity of the site. To address these problems, we have come up with a solution called Loqui. Loqui is a digital tool for efficient communication between all stakeholders on the construction site, namely the site coordinator, the supervisor, and the construction worker. The application is tackling the alarming statistics of communication being the single most time-consuming item in the coordinators' daily work schedule and adding to it, existing digital solutions failing to pass the adoption hurdle posed by the construction workers as the end users. On the top layer, the application provides a dashboard, clearly depicting the project structure which is comprised of tasks, their deadlines, and the workers assigned. The coordinating role can create multiple project instances, decompose it into smaller units and assign them to individuals or groups with an associated deadline. The executing role can view all relevant tasks including priority, location, description, associated team members, and due date. Also, the worker can indicate that he is working on a specific task and mark it as 'to-be reviewed' if it has been completed. The update of workflows is implemented by a simple drag-and-drop functionality, emulating the concept of 'Kanban boards' which find their origins in the software development industry. This core functionality is supported by automatic notifications for task updates to inform the respective supervisor about the project progress or delay on the one hand but also to notify preceding or succeeding subcontractors about potential delays which they are dependent upon. This helps bridge the communication gap between subcontractors in a highly synchronized workflow setting. The value of this application increases with the size of the project and the number of stakeholders involved and helps to manage this complexity. Another function that soothes the pain of the surrounding residents is the provision of the dashboard via a QR code attached to the construction fence. This dashboard is enriched with information about the current phase of the construction process and estimates of water and electricity downtimes as well as loud noises coming from the construction site.

Business Model

Key Partners

- All stakeholders involved in on-site work assignment plus sales network
- Hardware manufacturers
- BIM software developers
- Industry associations
- Construction companies
- Cities

Key Activities

- Product development
- Maintenance of screens
- Sales
- Customer support
- Onboarding training for managers and workers
- On-site screen installation

Key Resources

- Software
- Screens
- Human capital (back office, sales, developers)
- Data (for continuous improvement of automatic scheduling)

Value Proposition

- Process transparency
- Trust towards subcontractors
- Cost reduction
- Reduction of the language barrier
- Planning security
- Easier work delegation
- Reduction of paper work
- Public information
- Convenience to construction workers

Customer Relationships

- Intense and direct relationships
- Feedback integration
- Relational sales process

Channels

- Online in-/outbound (targeted advertisement, LinkedIn, newsletter, blog)
- Offline in-/outbound (phone calls, billboards, pilot projects/prototyping)
- Directly approaching target customers (large construction companies, architects) via exhibitions, uni network, on-site visits

Customer Segments

- Small- and medium-sized construction companies, their subcontractors and architects/project planners

Cost Structure

Fixed Cost

- office space
- IT infrastructure
- human resources

Variable Cost

- sales employees
- cloud storage

Revenue Streams

- SaaS fees
- Affiliate partners
- Technical support
- Consulting

Pricing model:

- Basic: installation, onboarding training, basic support
- Premium: installation, onboarding training, continuous premium support

Value Proposition

Often, a lot of site supervisors complain that most of their day is wasted in running around to ensure everything is in order. In order to solve this problem, Loqui is a digital tool to make communication more efficient and effective on the construction site. While researching the feasibility of our tool, we came across other pain-points that could be addressed with the help of our platform. In an effort to enhance the construction process, we aim to develop a tool that addresses these problems.

Reducing the need for interaction: Supervisors will be able to delegate tasks directly to individuals or groups of workers through the application. Also, workers can view a to-do list of tasks assigned to them with information on where it is to be performed. After completing the task, the worker can update the progress, thereby sending a notification to his supervisor, who can then review the task. Apart from this, the supervisor can also 'request to review' a certain task. Consequently, there is hardly any need for physical interaction between workers and supervisors.

More reliable communication: Currently, communication is done verbally or on paper, which is subject to damage or getting lost. With Loqui, all communication is in digital form. Therefore, everything is automatically documented and stored for as long as required. The information could be used in other projects or at a later stage in the same project.

Faster communication: Construction projects running overtime is very prevalent. By reducing the number of face-to-face interactions between the workers and supervisors, we contract the direct task assignment via mobile devices between the involved parties. Therefore, enabling faster decision-making and reducing idle-time between tasks.

Increasing transparency: Since all tasks are well documented, and to some extent standardized, there will be no discrepancy between what workers are supposed to do and what they think they have to do. Also, the supervisor will tend to give more work to a certain worker if he has always completed his work and updated the progress on time. Also, people working and residing near the construction site can easily scan a QR code on the fence in order to know a basic schedule of the noise, electricity and water downtime.

Customer Relationships

With an already customer-centric approach, it is very important for us to keep the customer satisfied at every step of the construction process. Being new to the market, we want to involve the clients' opinion even in the development phase to come up with a product that caters to their needs.

Intense and direct relationships: We seek to establish an intensive customer liaison and support with active key account management. If the user expresses a difficulty, then he can directly contact his customer success manager, who would either provide him with a solution or set up a meeting to discuss and resolve this issue. This would leave the customer with a sense of comfort as well as safety while using the product.

Feedback integration: Another important factor is to gather feedback from customers and include them in the product development process. If the user reports a problem in the functionality or an interface glitch, we plan to reward him with benefits such as a discount on 'x' number of users per month. This would further incentivize the client to provide feedback and help us create a better product.

Relational sales process: Having a SaaS-based model, we will be taking proactive strides to engage the customers with online content, mails, and regular events. A healthy relationship with the customer will make it easier for him to approach us in case of an issue instead of directly switching to another tool or unsubscribing from the service.

Channels

To maximize Loqui's reach, a well-rounded mix of offline and online channels is utilized with a slightly stronger emphasis on offline measures to conform to currently used communication channels. Since our product is an application, no production facilities or logistics network is required. In the aspect of distribution channels, we make use of online and offline marketing channels to reach out to our target audience.

Online: Although sales processes in the construction industry are usually done via phone, online marketing channels provide us with the opportunity to target specific groups with our advertising content. Such channels would contain targeted advertisements on social media platforms like Facebook, where you can narrow down your target audience according to personal and professional criteria. Professional networks such as LinkedIn also provide opportunities to reach out to your target audience. In contrast to reaching out to your customers directly, we plan to gain traction by providing proprietary content in the form of newsletters and blog posts. Furthermore, leads could be generated by the contact form provided on the Loqui website.

Offline: Calling on more traditional measures, we aim to employ sales personnel to reach out to potential customers via phone. Billboards on highways and in cities can also be utilized to generate leads. But, most importantly, we aim to

provide live demonstrations on the construction site with trained sales personnel to prove the efficiency gains offered by our solution.

Key Resources

To establish Loqui, we require a set of resources that contribute to developing the product, selling it to companies, providing support to clients, and managing the organization effectively.

Technology and Data: The software product is at the core of the organization. All the programs written and data stored will be the basis for developing the tool from scratch. Also, all the added features will only be built upon the minimum viable product. Once the software is implemented in different projects, acquiring data will be of prime interest. After being used in multiple projects, this data will be our key resource for further development. In the initial stage, we focus on predicting time and resources needed as well as automatically allocating tasks by predefined and user-defined functions.

Human Capital: Structuring the organization to maximize the output, we have talented and enthusiastic people who are willing to take ownership of their task. Setting up teams: development, marketing, sales, and management will require more people to partake in helping Loqui make a strong entry into the market. At each stage of product development as well as feature addition, there is a team of excellent programmers and system architects to integrate all of the code into a single product.

Key Activities

Being the first product of its kind in the construction industry, a large part of the resources will be allocated towards the development, sale, and implementation of the product. A major challenge for us would be to get clients to adopt and become accustomed to using digital technology over conventional methods for planning and communication. To enable them to smoothly make this transition, we would have to develop a very intuitive user interface in addition to mirroring the current workflow for every user in the application.

Product Development: After having identified all the pain points and analyzed the feasibility, we plan to design, program, and integrate them into a software solution to develop a minimum viable product. This would enable easy task delegation as well as progress tracking, and the neighbor is informed of the construction schedule at the same time. Additional features will be included in a continuous process based on feedback from the Loqui team (Alpha testing). Subsequently, we hope to do a pilot project with a construction company to receive input on the functionality and user-friendliness. Only after having developed a robust product that creates value for our customers, do we plan to release our product.

Onboarding: After the purchase, each client will be allocated a customer success manager that ensures the complete onboarding process of the client onto the platform. We will provide support from installing the software and inputting data to a detailed demonstration for the workers on how to check and update tasks.

Revenue Streams

SaaS fees: Construction companies are offered the opportunity to sign up for Loqui and pay on a monthly basis per user. Since the value increases with each acquired customer, user-based pricing was chosen. The customer can unsubscribe at any point in time for the next month and can sign up again, e.g. when the next construction project starts. Thus, Loqui aims to provide a flexible solution tailored to the specific need of the construction industry to cope with planning uncertainty. The fees vary between small and medium-sized companies, who are paying 29.90€ per month per user with a slight premium over large companies with more than 25

employees who are charged with 24.90€ per month per user.

Training/Customer Support: To increase the adoption of the digital solution and resolve potentially arising issues beforehand, we aim to provide introductory courses for supervisors and construction workers alike. If further issues arise during work on the construction site, we also provide customer support via a helpline. Both services can be charged independently from the core SaaS model.

Smartphone leasing: To increase adoption of the construction workers and create an additional revenue source, we want to cooperate with smartphone manufacturers to lease out smartphones to potential users, who do not own one.

Key Partners

Keeping multiple stakeholders in mind, our solution addresses problems at multiple levels. To facilitate this interconnected process, we would require partnering with several individuals as well as companies. Establishing a two-way relationship, we aim to combine our efforts with the end goal of providing excellent service and user experience to everyone associated with us. Below is a list of the stakeholders involved in on-site work assignment plus the sales network:

Construction Companies: The first stakeholder involved would be the construction company that adopts Loqui. Since they are the party paying for the service, they will also reap maximum benefit from the tool.

Smartphone/Tablet providers: With the intention of providing everyone on the construction site with a mobile device, we plan to collaborate with companies that sell or rent these devices for our application. These devices will be procured and delivered on demand to Loqui members who do not have a smartphone. If rented, the devices will be provided for the subscription duration.

Industry Associations: Exploiting the network of large industry associations, such as the German Construction Association ("Zentralverband Deutsches Baugewerbe"), would be of vital importance to generate leads and gain additional traction in the construction industry.

Customer Segments

In general, Loqui focuses on the project managers and construction workers on the construction site. However, the customer is the construction company itself. As the product pricing varies with the size of the construction project, it makes sense to segment the customer base by size.

Small- and medium-sized construction companies: This segment is, by far, the largest in Germany which makes it attractive from a market size perspective. For smaller companies, the ratio of the amount of time saved per employee to the total money spent is higher. Hence, small and medium-sized companies have to pay a slight premium for the application usage.

Large construction companies: Although there are relatively few companies in this segment, the value of the application increases disproportionately with the size of the construction project. Despite the time savings per employee being smaller than with small and medium-sized companies, the perceived value is significantly higher, which makes this segment the most attractive for Loqui.

Cost Structure

Fixed costs: Regardless of Loqui's success, there are running costs associated with operating the business. For instance, the company needs to pay for office space, associated supplies, and IT infrastructure required to store the customer's data. Furthermore, salaries that are not profit-related can be considered fixed costs as well. Due to the nature of the product being a smartphone app, the fixed costs are comparatively low.

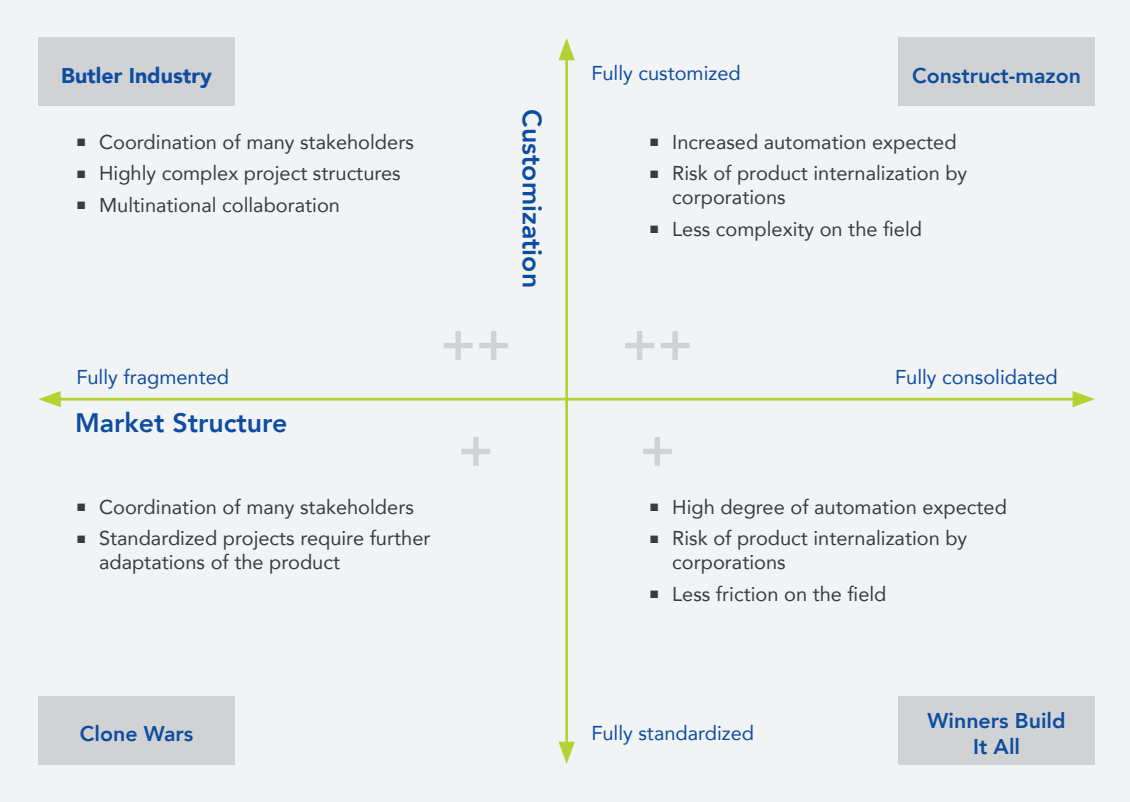
Variable costs: Profit-related salaries or ones for outsourced product development fall under this category. Besides that, all spending for marketing purposes is proportional to the output of increased product sales. The provision of customer support services also poses a variable cost position by buying from local service providers. The leasing of smartphone devices to construction workers would also require us to either buy devices for our inventory or share our profits from that revenue source with the partner.

Scenario Fit:

Butler Industry: A fragmented market would entail a greater number of stakeholders involved leading to a higher complexity associated with the construction process. This would create the need for a tool to effectively organize and manage workflows. As a result, Loqui would thrive in such a market. Also, a high degree of customization will amount to more variables involved in the market as well as the construction process. With more uncertainty in the demand and type of building, it would be helpful to have Loqui in order to provide some structure to the process and at least save time and effort spent in task delegation and getting updates. However, this might require us to tailor our tool every time to suit the needs of our customers. Due to an increase in demand in response to both the trends, the 'butler industry' extreme scenario would be probably the best case for our product.

Construct-mazon: This scenario is essentially what recently happened to the electronics retail industry. Having a fully centralized market, where only a few construction giants exist, would streamline the entire construction process. Each of these companies would have their approach, process, and very likely even their tool for construction management. Since the capital availability of those few companies will be large due to higher margins and synergy effects resulting from the centralization, there will also be an increased role of automation. This does not pair very well with the idea of Loqui and therefore, might be a major hurdle to stay on the market. To still have a stable market share, we would try to partner up with one of the construction giants and focus only on their process. On the other hand, having a customized market might still leave room for Loqui to be used because of the need to coordinate complex tasks that usually have not been done before.

Winners Build It All: In the extreme scenario of full centralization, only one or a few companies would employ all the workforce and oversee all construction projects. Since this aggregation of workforce eases its coordination, the need for our communication solution would decrease compared to today. Full standardization naturally decreases process complexity and reduces the need for visualization and coordination solutions such as ours. However, despite all workforce being aggregated under one leading company, our solution still provides value for prevailing problems such as reducing language barriers, streamlining feedback loops and synchronizing tasks. Although this scenario is among the least favorable, Loqui would still be able to provide value to the



construction site, especially with planned functions such as automatic schedule generation or modularized processes.

Clone Wars: In a fully fragmented market, there is a large need for roles and functions coordinating the many stakeholders in the construction process. Since Loqui aims to solve the problem of complexity arising from the increasing number of stakeholders, this extreme scenario would prove to be highly favorable for our business idea. On the other side, a full grade of standardization in the construction process being coupled with full fragmentation will favor automation, which would, in turn, reduce the need for our solution due to the decreased amount of human labor. However, since our product roadmap contains the modularization of process tasks for reuse purposes, higher standardization would foster the usage of this already useful feature. Overall, Loqui would be a competitive product in this scenario.

Challenges:

- The existing adoption hurdle for digital solutions must be overcome.
- The adherence to the technology roadmap is dependent on the general adoption of BIM in the construction industry.
- The market is competitive with similar service providers.

Outlook:

Once Loqui establishes itself on the market, having been used for different kinds of projects and also multiple times for similar projects, we are eager to release several other features expanding the capabilities of the software. With more usage data gathered, we envision analytics options on the supervisor dashboard, enabling him to track the performance of each worker and an accurate time as well as resource requirement estimation based on current and previous performance. Moreover, we plan to integrate with BIM software in the near future. Initially, the users – supervisors and workers – will be able to view a 3D model of the plan. Supervisors will directly be able to assign tasks in BIM and the workers will be able to see exactly where the job is to be done. Our eventual goal is to combine data analytics and BIM to develop a tool which would require minimal input or none from users; a BIM model directly translated into mid-level and granular tasks and automatically assigned to members based on their skills, experience, and performance.

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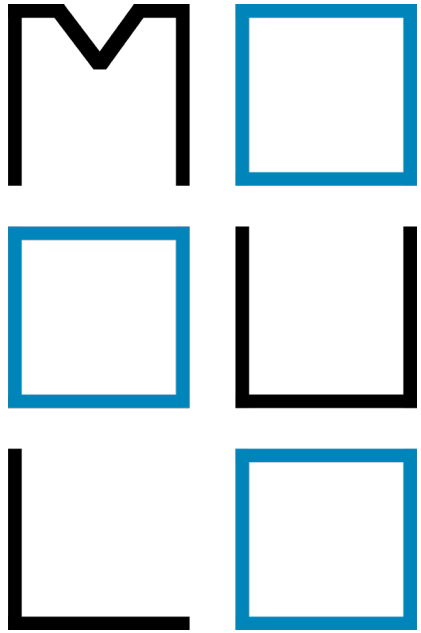


MODULO

Customizable Modular Apartment Solutions

The shortage of affordable living space in ever more dense urban areas is one of the most pressing issues in Germany and around the world. The advantages of modular building methods are apparent – low building costs, short fabrication time, and effective use of the scarce available space. However, modular construction and prefabrication have been mostly applied to the serial construction of, for example, hotel rooms, where customization is not required. As projects like residential buildings require a higher level of individualization, the benefits of this construction approach have not been leveraged efficiently to meet customer demand. Modulo resolves this by offering modular, prefabricated apartments which can be customized and ordered online. These modules have standardized outer dimensions and can be "plugged" into matching slots of a Modulo frame, a pre-built multi-story structure on-site.

To cover the demand for available slots with the supply of frames, Modulo partners up with project developers who buy frames from Modulo to offer slots in urban areas across the country. On the Modulo website end users can then buy available slots and configure and order according to modules. Each ordering process can be done completely online. In case of questions, customers can request consultation on design and usability by an in-house expert. The customer order is then forwarded to a production partner who prefabricates the module. Upon completion, the module is transported to the construction site and installed into the project developer's frame. Modulo thereby connects end users with project developers and with the help of digital technology captures the sweet spot between standardization and customization.

Business Model

Key Partners

- Project Developers
- Construction companies
- Prefabrication companies manufacturing modules
- Logistics companies transporting the modules
- Subcontractors installing the modules
- Interior and add-on service providers

Key Activities

- Development, maintenance, and advancement of the Modulo online-configurator
- Maintaining a database of available slots and frames
- Organizing the manufacturing, transportation, and installation of modules

Key Resources

- Modulo configurator
- Data and templates on best practice designs
- Design experts and know-how
- Patents on standards and solutions

Value Proposition

End User

- Affordable living
- Short fabrication and transport time
- One-stop shop solution
- Customization possibilities
- Fixed price and completion date guaranteed

Project Developer

- Customer acquisition
- Comparably low initial investment
- Reduced risk and organizational overhead

Customer Relationships

End User

- Online and personally assisted selling process
- Provision of functional best practice design templates

Project Developer

- Personally-assisted co-creation
- Individual consultation

Channels

End User

- Online & Offline Ads
- Websites including Modulo's online configurator
- Showrooms

Project Developer

- Industry exhibitions and fairs
- Direct marketing and sales

Customer Segments

End User

- Students
- Young professionals
- Young families

Project Developer

- Private project developers
- Municipalities (social housing, office spaces, affordable living space)

Cost Structure

Fixed Cost

- Human resources
- IT infrstructure

Variable Cost

- Payment of suppliers and partners
- Material cost

Revenue Streams

- Margin on module sales
- Affiliate margin
- Margin on frame sales

Value Proposition

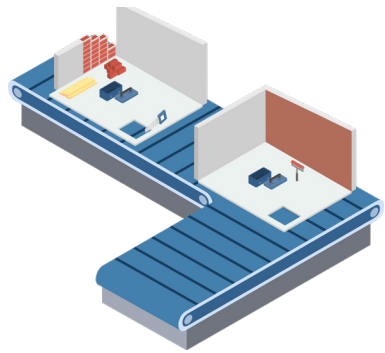
End User: The standardized design and fabrication of the modules allow Modulo to sell affordable apartments to end users directly. Through the online configurator, the process of designing and buying modules is simplified as much as possible. From the size of the bathroom to the painting and floor material, the customer can easily customize his or her module(s) according to personal preferences and needs. To guide the user through this process, best-practice solutions for different sizes, requirements, and preferences are provided. To meet different size requirements, modules can be connected to form an apartment unit. The online configurator serves as the single touchpoint and offers the customer a one-stop shop solution. The system of frames and modules, as well as the comparably high degree of standardization, allow prefabricating the modules. Consequently, the customer benefits from a guaranteed price and completion date.

Project Developer: For project developers, Modulo offers attractive investment opportunities with a comparably low initial investment, as well as reduced risks and organizational overhead. The construction method of using a frame and modules, which are plugged in later, allows the investor to provide the initial investment for the frame only. As the modules are directly paid by the end user, the project developer does not need to cover these costs and lowers his investment risk. The high degree of standardization and prefabrication reduces the risk of overrunning time and budget since construction defects, and change requests are minimized and material utilization optimized. This also leads to a lowered organizational effort for the project developer during the building phase. The effort for marketing and sales activities is reduced as well since Modulo supports with sales by putting available slots online and takes an active part in customer acquisition.

Customer Relationships

Online and personally assisted selling process with a single touchpoint: Modulo offers a very intuitive and easy way to configure apartments even for inexperienced customers. This can be done the very short amount of time without even contacting an architect or an interior designer. Customers can start designing their home by choosing from a list of templates and are guided through the customization process with hints and best practice examples. The configurator detects unfeasible or undesired details and alerts the user by giving suggestions on how to solve the design challenge. At the end of the configuration process, an expert reviews the design and further advises the customer. After the review, the apartment can be ordered and will be directly delivered to the construction site in a very short time, compared to conventional construction projects.

Personally-assisted co-creation and individual consultation: Modulo maintains a very close relationship with project developers, who are at the same time key partners and customers of the company. Modulo supports them during the planning phase of their building by assigning a key account manager to each project developer to maximize the service quality and optimize the outcome. After the completion of the construction, Modulo is still in close contact to ensure a smooth process for each ordered module. Moreover, Modulo cooperates with project partners in regards to marketing and sales activities of the available slots through the online platform. Once all slots are filled with modules, the collaboration concerning that specific object is completed. However, Modulo strives to establish long-term relationships with project developers to ensure recurring order and spread its modular construction method and establish a wide network of Modulo frames. This relationship is limited the construction process of the frames since Modulo does not offer maintenance services.another tool or unsubscribing from the service.



Channels

Online and offline ads: End users are mainly targeted and acquired through online and offline advertisement. Ads placed in real estate magazines or websites are expected to attract the most customers, both offline and online. Further offline ads will be placed in topic-related places for example as banners on (Modulo's) construction sites. Regarding online ads, Modulo will use search engine advertisement and optimization (SEA and SEO) and retargeting measures to increase its visibility and reach. Since Modulo targets a rather young customer segment, social media is expected to be a valuable channel.

Showrooms: In showrooms, potential customers can experience the look and feel of Modulo buildings in real life. Moreover, they can try out the configurator and get information about the entire purchasing process with very little effort. In this way, it is easy to convince customers of the high quality of life Modulo offers as well as the efficiency and the usability of the configurator.

Website including Modulo's online configurator: Once a customer has decided to buy a module, the main interaction will take place through Modulo's website and configurator. Through this channel, Modulo's key value proposition, i.e., the provision of simple design and supply chain processes, is delivered to the customer. In the event of changes after expert review, further communication and consultation can also take place personally.

Industry exhibitions and fairs: On exhibitions and fairs the configurator and a demonstration module can be presented to spread awareness of Modulo and, eventually, convince project developers of realizing their building projects with Modulo. In this way, project developers can be contacted directly, and the functionality and operations of Modulo as a construction method and company as well as its advantages can be pointed out easily.

Direct marketing and sales: Modulo's salesmen directly address project developers with cold calls and mailings to make the first contact and increase the company's recognition.

Key Resources

Modulo configurator: Modulo's core product is a browser-based application that allows the user to easily configure their living space. The user specifies her preferred apartment size and selects a location from a choice of available frames and slots. To support the user with the design of the module(s), the configurator suggests best practice solutions according to the use case. These can then be customized and, once finished, ordered with a few clicks.

Data and templates on best practice designs: By analyzing the customers' preferences and reviews, Modulo automatically defines best practice solutions. This data and templates are then used to advise new customers.

Design experts and know-how: Experts from Modulo prebuild design templates and review finished configurations before the final order. This helps inexperienced customers easily arrange their apartments without layout mistakes.

Patents on standards and solutions: Together with the manufacturing partners, architects and engineers at Modulo develop patented systems consisting of modules and frames that can be built and transported efficiently.

Key Activities

Development, maintenance, and advancement of the Modulo online-configurator: The development of the online-configurator is the main activity of the company. It consists mainly of implementing the configurator as a browser-based application and developing the backend. Modulo also provides its user's design advice by offering templates and best practice design solutions. These are developed by experts who adapt them to certain use cases and are iterated automatically while taking configurations and experiences from former customer configurations into account.

Maintaining a database of available slots and frames: When Modulo acquires new project developers as customers, it also expands its network of frames. To keep track of this additional living space and to include it in the configurator, databases need to be constantly updated. Customers can then choose their favorite location out of many different possibilities.

Organizing the manufacturing, transportation, and installation of modules: While the transport of the modules is carried out by a partner company, Modulo coordinates the process in order to optimize logistics. Modulo also coordinates the manufacturing process of the modules by synchronizing it with the delivery of the furniture and other facilities. On the construction site, a team of sub-contracted workers installs the modules into the frame.

Revenue Streams

The margin on module sales: As stated in the cost structure, Modulo does not manufacture the modules itself but has them produced by a cooperating construction company. Modulo charges the customers a margin of 10% on the module sales which is added to the price the construction company charges. However, the module configurator states the total price for the customer. Since Modulo has no impact on the manufacturing costs, the only way to scale its revenue is to increase either the relative margin per module sold, the number of modules sold or the value of individual modules.

Affiliate margin: In addition to the margin on module sales, Modulo also earns a margin of 10% on the sale of furniture and add-on services, which are installed into the modules.

The margin on frame sales: Project developers hire Modulo to build a frame on their building ground. Modulo commissions a partner construction company to build the frame and charges a margin. This margin currently amounts to 3% of the production costs. The total manufacturing costs depend on the volume of the project, meaning the lot size, height of the building, and total slots as well as the complexity of the project. Therefore, fixed pricing is not feasible. Sales growth

can be generated in the same way as for the modules.
In contrast to these, Modulo can choose from several subcontractors that build the frames. In case Modulo can find cheaper subcontractors that are equally reliable, it could lower the manufacturing costs and keep the same absolute margin. In that way, Modulo could boost its revenues as well.

Key Partners

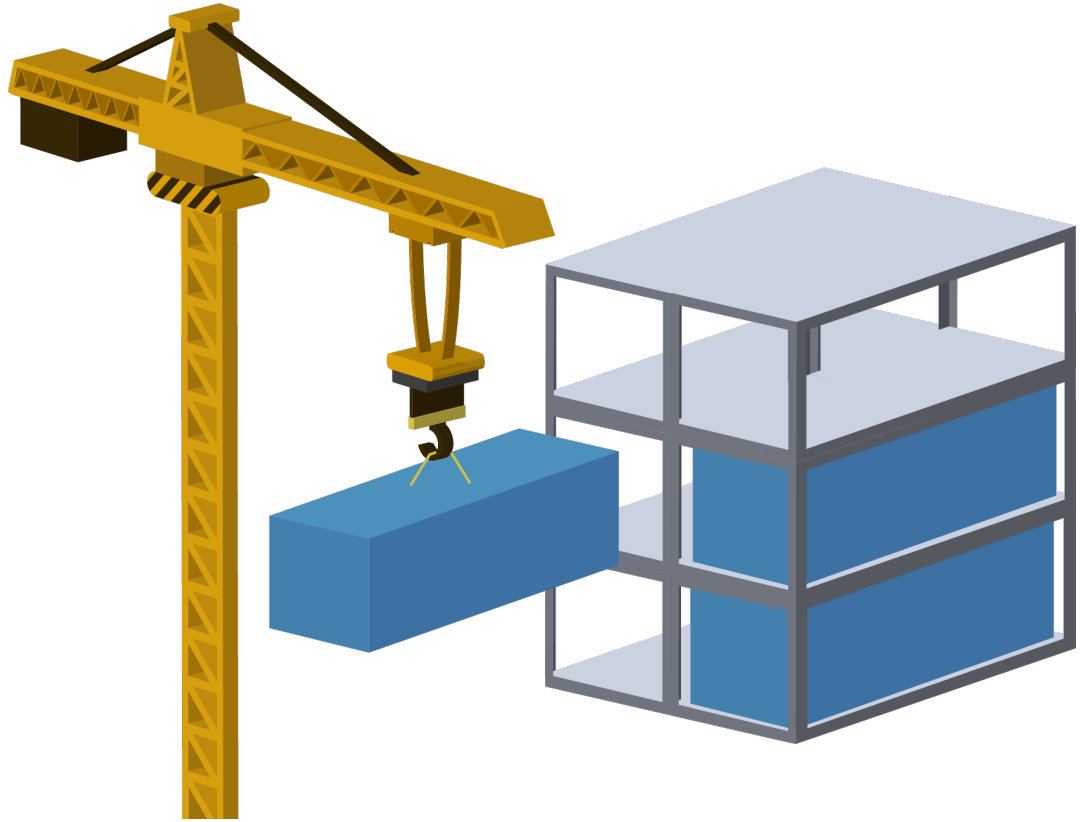
Project Developers: Being partners and customers at the same time, project developers hire Modulo to build frames for their real-estate projects and at the same time create additional locations and available slots for Modulo's end-users. As available building ground is a prerequisite for Modulo's offer, partnering with project developers is crucial.

Construction companies: For the construction of the frames, a construction company is hired. This company builds the standardized frames developed by Modulo. To ensure quality standards and a time-efficient building process a long-term partnership is intended.

Prefabrication companies manufacturing modules: Another strong partnership is established with prefabrication companies. This specialized company allows fast production of high-quality modules. It is important that this supplier is perfectly aligned with the plans and specifications generated by the configurator, as well as the entire production process. Logistics companies transporting the modules: This company forms a key element in the supply chain. It handles the transport of the prefabricated modules from the manufacturer to the construction site. In a future scenario, this company would also execute the relocation of the modules when a customer decides to move to another place.

Subcontractors installing the modules: At the arrival of the modules on the construction site, a trained team of workers insert the modules into the frame and connects the wires and pipes of the standardized interface. This simple and standard process allows hiring subcontractors which only need to complete a quick training.

Interior and add-on service providers: Other important partners are the suppliers of furniture and add-on services. During the configuration of the building, the customer chooses from their product range. The customer's selection is then delivered just-in-time during the manufacturing process of the modules.



Customer Segments

For its two-part construction method, Modulo targets a different customer group for each part: the general construction method, in particular frames, are marketed to project developers, whereas the modules are directly sold to end users.

End-user: The main customer segment of the modules are people looking for affordable living space, including students, young professionals, and young families. These groups have an interest in investing their money on a long-term basis instead of paying rent. Additionally, they prefer to live in cities and accept smaller living spaces. In return, Modulo can offer comparably cheap living solutions which can particularly attract young buyers. However, Modulo's building method could also be attractive for other customer segments such as older adults, fast-growing companies, especially start-ups with a need for additional office space, government and municipal entities or any other group that is in need of fast, cheap, and scalable living solutions.

Project Developer: To enable the building method, Modulo targets project developers that finance the construction of the frames. These property developers look for rather low investments compared to projects of the same size using conventional building methods. At the same time, Modulo offers a relatively high return on investment for the project developer. Besides corporate project developers, government and municipalities are potential customers for frames as well.

Cost Structure

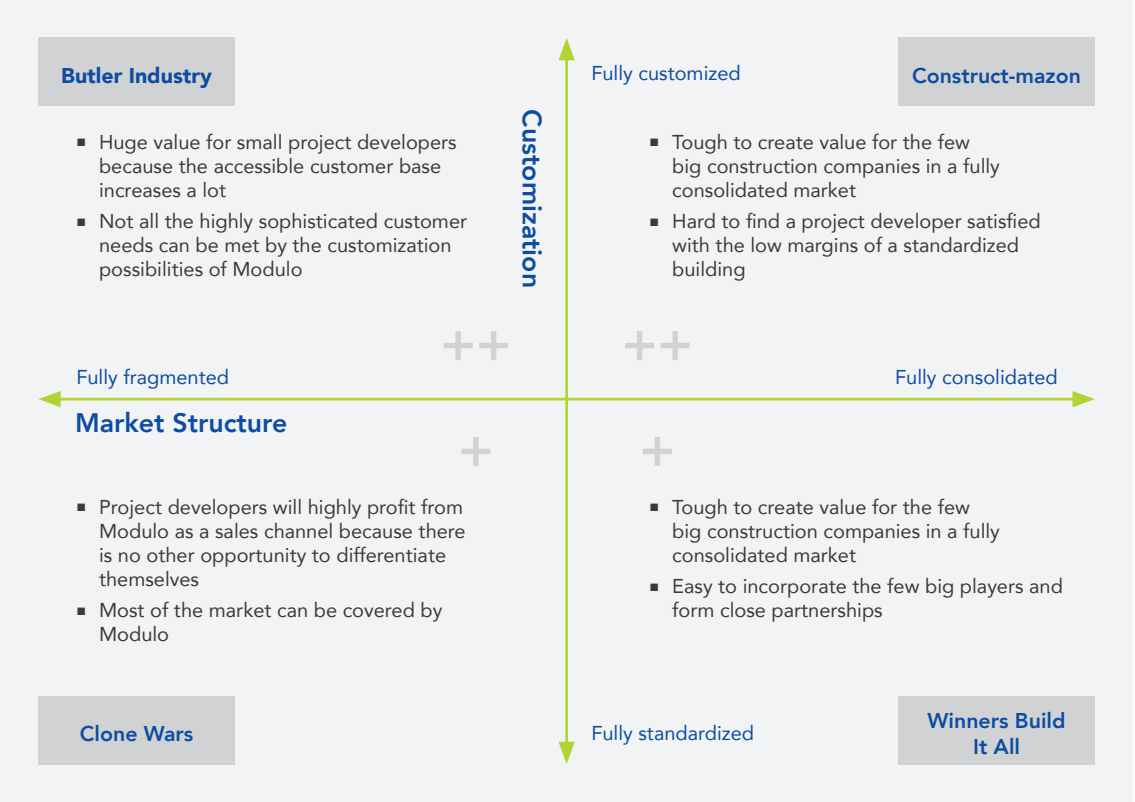
Internal employees: The largest item of fixed costs emerge from salaries, in particular, for software engineers, civil engineers, designers, architects, marketers, and salespeople. Software engineers develop and maintain Modulo's online configurator. Thereby, they enable one of the key benefits Modulo offers to both of its customer groups, end-users and project developers. Civil engineers, designers, and architects develop and improve the module and frame and make design recommendations. Moreover, they review customized orders before the final commissions and consult clients in cases of problems or questions. To increase awareness and improve the reputation of Modolu's building method, marketers and salespeople are particularly important in the beginning.

Payment of suppliers and partners: Modulo does not cover any of the construction stages. Incoming orders for frames and modules are only processed and organized by Modulo and forwarded to partners and suppliers that take care of the actual production and construction. Since the costs for manufacturing are borne by the supplier, Modulo's production costs are fully variable. They only accrue indirectly through the payments to executing construction companies for modules and frames. The level of variable costs depends mainly on the design of each project. Costs for suppliers and partners that occur along the supply chain are construction costs of the frames and the modules and transportation, furnishing and installation of the modules.

Scenario Fit:

Butler Industry: In a future where the construction market is fully fragmented, Modulo provides a lot of value for small project developers because it largely increases the customer base accessible to them. Furthermore, the required investments for a Modulo frame are far below classic residential buildings of comparable size, so it is also possible for smaller players in a fragmented market to initiate a Modulo project. However, the modules, even though customizable, will not be able to meet all specialized customer needs. A focus on core customer segments such as students and young families, who have only a limited budget and particularly value the price advantage, is therefore necessary. An advantage of this scenario can be the special status Modulo will likely occupy as it offers the benefits of standardization without neglecting the demand for customization possibilities. Nevertheless, Modulo's business model is not a perfect fit for the "Butler Industry" scenario.

Construct-mazon: The acquisition of project developers will be tough for Modulo in a world with a fully consolidated construction market. The few big construction companies will likely cover the project development part of the value chain themselves and lack incentives to pay Modulo for tasks they can easily perform on their own. Added to that, the margins on the highly customized buildings the construction companies can offer are probably higher than those on standardized Modulo solutions. On the other hand, it will be easy to incorporate all the projects of the few big players on the plat-



form, which makes it very valuable to customers. The focus for Modulo in this scenario will be the module configurator, which could be sold as a white label solution to project developers and construction companies without setting up a Modulo platform.

Winners Build It All: The disadvantages of a consolidated market described in the "Construct-mazon" scenario also apply for this scenario – attracting project developers to the platform will be a challenge. In a fully standardized world, another issue is the likelihood of competing standards for modular apartments, which might make it even harder to find construction companies to finance and build the frames. Again, the focus of Modulo will be the module configurator as a tool offered to the dominant market players, independent of the platform. Because they offer standardized solutions, the configurator has immense value for the major construction companies as they can respond to more individual customer needs while still being able to compete with the prices of fully standardized solutions. That makes selling the configurator a highly feasible business model for Modulo in this scenario.

Clone Wars: Modulo can cover most of the market in this scenario as it offers standardized solutions but is also attractive for people who still value customization possibilities, which is a competitive edge in the market. Project developers will highly profit from Modulo as a sales channel as they do not have any other chance to differentiate themselves in a world with fully standardized solutions. The low required initial investment and reduced risk come into play as additional advantages that Modulo offers for project developers. In this scenario, the number of possible suppliers for the modules and frames is high, and Modulo, therefore, possesses high market power. This allows Modulo to earn higher margins and to offer lower prices. In summary, the "Clone Wars" scenario is a perfect environment for the Modulo, business model.

Challenges:

- High upfront R&D effort to develop the customizable modules and the corresponding frame
- Exploiting the benefits of a standardized solution while leaving enough room for individual customization to meet customer needs in the fully standardized as well as the fully customized scenario
- Getting project developers on board, especially in the beginning and if they have a powerful market position
- Finding reliable and cheap suppliers that prefabricate the modules and the frame as well as companies that supply the interior and add-on services
- Management of the logistics of the module and all furnishing as well as add-on services to have everything ready for assembly in time

Outlook:

Modulo aims to be the main provider of affordable living space in an ever more dense, fast, and mobile world. A network of Modulo frames across the country will enable end-users to freely choose from different locations for their new self-designed home and even move to other Modulo frames by taking their modules with them. This will offer people flexibility regarding their residence which they already have in other areas of life. Also, buildings will not have one static and eternal use anymore. If a city, for example, decides to repurpose a frame initially built for social housing to a retirement care home, this can be easily done by exchanging the modules. With Modulo, the world we live in will be able to adapt much faster to the changing requirements of society and every individual that is a part of it.
Along with this journey, Modulo gathers valuable data on customer preferences regarding housing, furnishing, and other add-on services. By leveraging this, it will be possible to extend the current business model. Various functions like sales of household items could be integrated into the Modu-

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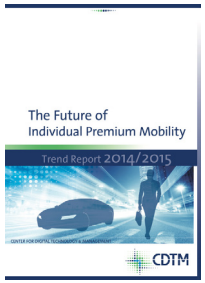

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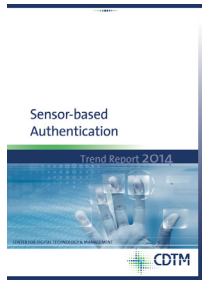

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THE DIGITAL FUTURE OF THE CONSTRUCTION INDUSTRY

Digital technologies are constantly pushing us towards an ever more connected world and have a significant impact on our daily private and business life. Whereas our living environment becomes more and more reliant on digital technologies, the construction industry – responsible for building this environment – is still almost entirely detached from the digital age.

However, with the increasing complexity of future cities, new technologies – such as the Internet of Things (IoT), Big Data Analytics, and 5-D building information modeling (BIM) – provide an ideal starting point to enable the shift towards a digital construction industry. This opens up new potentials for more efficient and sustainable construction processes on the one hand and new business opportunities for construction contractors on the other hand. But which technologies are best suited for shaping the future of construction? How will the built environment and the urban-rural relationship be shaped by digital technologies? How can digitization enable profitable building on a district level? And what are the implications for construction contractors in Germany, and especially Bavaria?

This report identifies current trends (political, economic, social, technological, environmental, and legal) that affect the digitization of the construction industry and derives four future scenarios as well as five related business ideas. The generated business concepts range from using Augmented Reality (AR) technology to guide construction workers, making task coordination easier for construction project managers, providing pre-fabricated modular buildings, enabling the use of IoT devices on the construction site, to a voice assistant instructing workers on site.

CDTM CENTER FOR DIGITAL TECHNOLOGY AND MANAGEMENT

The Center for Digital Technology and Management (CDTM) is a joint interdisciplinary institution of education, research, and entrepreneurship of the Ludwig-Maximilians-University (LMU) and the Technical University of Munich (TUM).

Building on the strengths of two of the most prestigious universities in Germany, CDTM provides highly qualified and ambitious students with an excellent academic education in the field of emerging digital technologies. As a research institution, CDTM closely cooperates with the industry, concentrating on telecommunication, information technology, media, entertainment, health and energy sectors.

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