wbcsd

Digitalization of the built environment

Towards a more sustainable construction sector

ARCADIS

Contents

Foreword

The digital revolution is transforming our world in the most profound ways and the pace of change is accelerating exponentially. Many companies realize that to ensure business continuity, they must learn to adapt to digital disruption. But knowing how to start and where to navigate is not an easy task. Therefore, the vast opportunities of digitalization are not fully captured yet, which is particularly the case in the construction sector.

Digitalization has the potential to increase efficiency throughout the value chain of the built environment, as well as to reduce resource consumption and CO_2 emissions. It offers the possibility to develop new processes, services and markets. It will increasingly transform the way we build, share information and take decisions in the construction sector. If done right, it can bring a multitude of co-benefits for stakeholders spanning the full length of the value chain, such as improving transparency and enabling more efficient and sustainable construction.

In the construction process, digitalization facilitates the rapid sharing and dissemination of information, allowing companies to test ideas, analyze large amounts of information and solve complex problems in a fraction of the time required by traditional methods. In the operational phase, digital tools can provide occupants with more control over the environmental conditions of buildings, while owners and operators can gain efficiencies in managing assets.

Despite the evident benefits, the sector has been slow to fully embrace the emerging digital opportunities. This resistance can be attributed to a handful of key factors: the cost of change, the fragmentation of the industry, inadequate collaboration with suppliers and contractors and insufficient knowledge transfer from project to project.

This report, developed with the contribution of our members, maps how digitalization enables sustainability in the buildings and construction sector. It shows how digital tools can serve to reduce emissions, resource consumption and costs across the value chain, whilst also increasing productivity.

The research also explains how digitalization supports full life-cycle management of buildings, including the time of use (user interface) and end-of-life/circular management. The paper concludes by providing a selection of recommendations for organizational transformation, at both company and sector level.

Digital transformation can be challenging. A considerable shift in organizational culture will be required for many companies, as well as addressing the workforce and labor concerns that digitalization brings with it. However, if correctly applied, digitalization holds huge potential for accelerating the transition toward sustainability within the buildings and construction sector.

Executive summary

In a world strained by climate change and resource scarcity, sustainable practices are increasingly becoming key prerequisites for ensuring business continuity and strengthening the public image of companies. For the built environment, digitalization is a key sustainability enabler. By helping actors across the construction sector increase productivity and transparency while reducing emissions, resource consumption and costs, digital tools can help companies establish and optimize their sustainability performance.

Digitalization and data-sharing can help businesses respond to the growing demand for future-proof buildings and lead to direct financial benefits. In the UK alone, it is estimated that an increased exchange of data could deliver an additional GBP £7 billion per year in the infrastructure sector.

This report was developed as part of the WBCSD project Transforming the Built Environment and is based on a literature review, a survey and interviews conducted with companies and organizations that have already embarked on a digital transition. The purpose of the report is to map how the construction sector is currently using digital tools to advance efficiency, transparency and innovation and to identify the actions needed to accelerate digital development towards a sustainable future of the built environment.

DIGITAL TECHNOLOGIES TO ACCELERATE SUSTAINABLE TRANSFORMATION

The application of digital technologies has the potential to fundamentally improve the sustainability performance of the construction sector in all aspects of its business: operations, compliance, communication and disclosure, and finance. Success across all of these aspects increasingly depends on organizations' ability to collect, manage, analyze, apply and report on sustainability performance information, as well as effective information exchange along the value chain. Specifically it enables companies to:

Manage complex information. Digital building technologies allow stakeholders to successfully integrate and evaluate different data and insights to inform the decision-making process. This is essential to ensure that sustainability goals are met when designing and executing construction projects in dense urban areas where many variables (related to mobility, pollution, nature, water, energy, materials and others) need to be taken into account.

Improve decision-making. Digital design tools (3D and 4D, computer-aided design, etc.) allow organizations to visualize, compare, anticipate and understand the implications of different solutions and decisions at the very early stage of a project, helping address circular economy and sustainability as a whole in an accessible way. Decisions can be based on a complete set of information, provided by building information modelling (BIM) for example. Also, material passports can help to better forecast the availability and quality of materials ensuring better design and construction decisions.

Ensure transparency and accountability. Digitalization enables the collection, processing, analysis and disclosure of large and complex sets of data. It is perceived as a key enabler for transparency and disclosure at several levels, including intra-organizational, inter-organizational (along the value chain) and to the public. Data-driven and science-based approaches to the collection, management and reporting of sustainability performance information allow organizations to continuously monitor their operations, prevent incidents and target interventions for performance improvement.

Drive sustainable productivity. Automation and standardization of design and construction processes can improve resource efficiency, lower construction time and increase safety, as an example, prefabricated components can be easily assembled on-site with limited manual labor. Blockchain technologies and an 'Internet of Materials' (i.e. a cloud-based platform for material exchange) can also support resource efficient design and construction.

Optimize resources. Digital solutions can allow stakeholders to better understand how resources flow in operations by tracking and tracing materials throughout the life cycle of a building, thus enabling further reuse. A digitalized design phase, using 3D to 6D modelling or digital

twins, can optimize resource use during the construction, maintenance and end-of-life phases by enhancing data sharing and decision-making with multiple stakeholders.

Reflect the end-users' needs in design. 5D design, augmented reality, virtual 3D and other innovative applications allow end users to make informed decisions, select materials or customize furniture and influence design space. End users can feed information back into maintenance and utilities information systems, thereby enabling resource optimization in, for example, energy use or maintenance activities.

Connect life-cycle phases. Digitalization can also enable concerted action for creating efficiency and transferring knowledge from one construction phase to the next. Information about design, construction, maintenance and disassembly can be shared amongst partners in the life cycle to achieve optimization of resources. This requires exchange of robust data and characteristics of materials and elements.

DIGITALLY ENABLED COLLABORATION

To accomplish the collaboration and information exchange required for sustainable and circular practices, the construction sector will need to overcome its deep-set culture of resistance to change and embrace a more open and collaborative mindset.

Digital solutions, in particular platform-based technologies, have proven to be powerful accelerators of value chain and life cycle integration in other sectors. The implementation of platform technologies, however, requires substantial investment in terms of effort, resources and change management.

Development of harmonized and standardized data sets, management approaches and disclosure are prerequisites for this transformation as has been demonstrated from other sectors' successful journeys towards digitalization.

UNLOCKING VALUE THROUGH HORIZONTAL AND VERTICAL INTEGRATION

The findings presented in this paper underscore the need for integrated approaches for digitally enabled sustainability. Digital transformations, however, are challenging to navigate. Technology is hardly ever the problem: digitalization as well as sustainable practices require a cultural shift, where value rather than cost is emphasized, long-term fundamental improvements are prioritized over short-term (project) objectives and innovation is conceptualized as a result of collaboration.

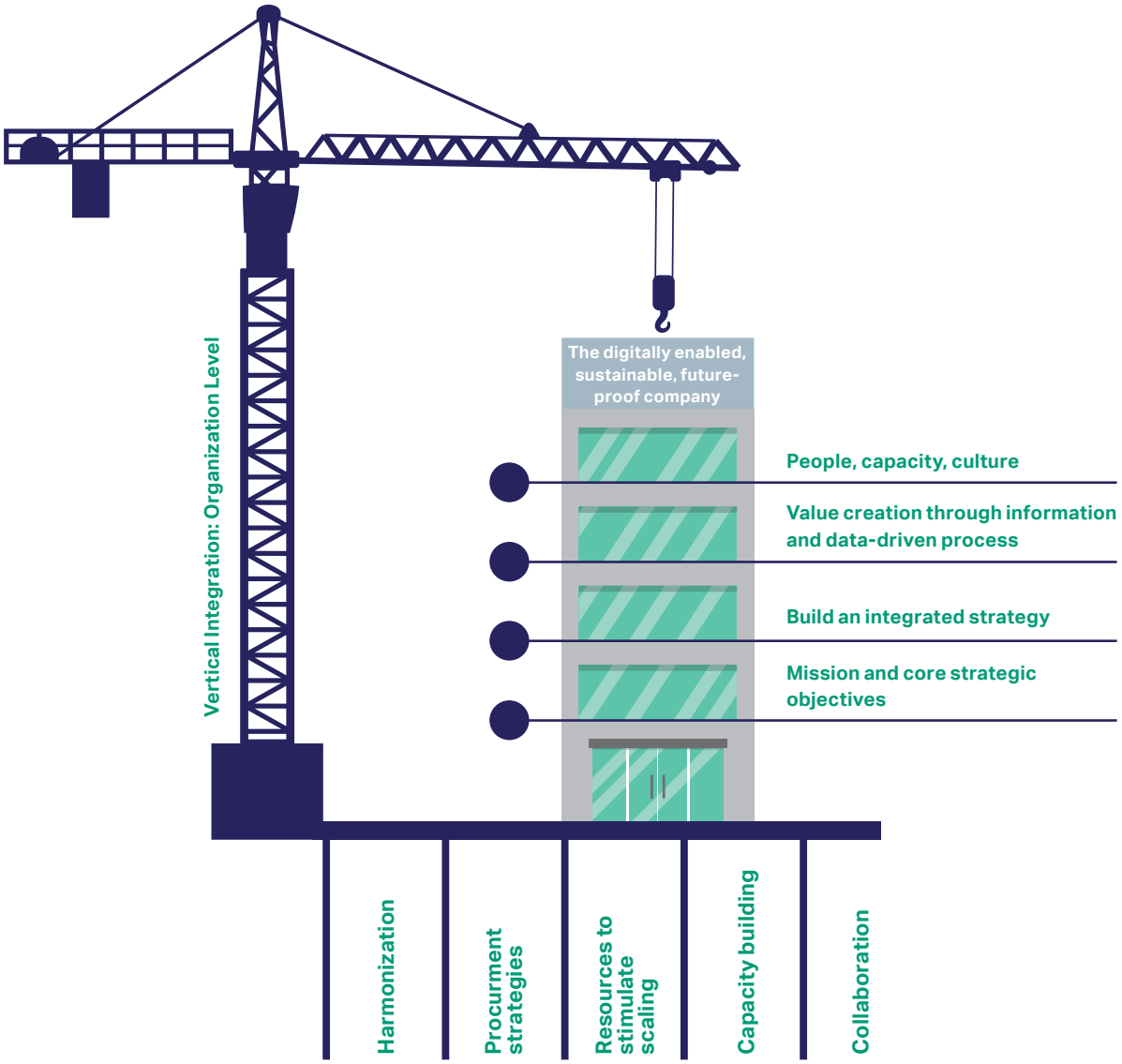
Individual companies can take several actions to stimulate **vertical integration** to accelerate progress toward digitally supported sustainable practices. Based on the conducted interviews and literature review, the following recommendations for companies have been derived:

- Reflect on the mission and strategic objectives of the organization and assess to what extent these core values are embedded in the wider business practices and results. This should include a comprehensive assessment of the organization's sustainability impact in consideration with challenges such as resource scarcity and climate change.
- Build an integrated strategy in which sustainability and digitalization are equally embedded into all areas of business, activities, distribution channels, tools and resources.
- Stimulate cultural and behavioral change by demonstrating leadership, supporting cross-collaboration, critically evaluating the long-term efficacy of existing business practices and seeking out change agents.
- Recruit staff with the right skill sets and invest in creating awareness and capacity building within the existing workforce.
- Encourage the shift toward data-driven and innovative approaches to design, engineering, production and construction.

At sector level, **horizontal integration** can be supported by governmental, institutional and sectoral actors to further stimulate sustainable practices and digitalization in a number of meaningful ways:

- Regulatory bodies and sector representatives can stimulate harmonization and standardization of data, processes, systems and accessibility.
- Institutional actors can support capacity and knowledge development by raising awareness of the value of digitalization for sustainability.
- Governments can provide incentives to scale innovation and resources to pilot.
- Policy makers can reform procurement practices and regulations to encourage innovation and sustainable outcomes in the built environment.

Figure 1: Elements of vertical and horizontal integration



1 Introduction

1 Introduction

The construction sector needs to fundamentally change its routines in order to ensure long-term business continuity while at the same time addressing the challenges posed by climate change, resource scarcity, continuing urbanization and changing market demands.[1]

1.1. THE NEED FOR CHANGE

The built environment

The built environment impacts our everyday lives. The development of healthy, safe and sustainable living and working environments requires the collective effort of a wide range of actors in the construction sector, from design and engineering, to resource production, transportation, distribution and maintenance.

In the recent decades, the construction sector has taken initiatives to become more circular and more sustainable. This journey has presented new opportunities for the construction industry and value chain.[2] However, the challenges ahead are huge: climate change and resource scarcity will adversely impact a smooth transition towards sustainable practices and a future-proof built environment.[3]

NECESSITY

The various manifestations of climate change, such as changing precipitation intensities and drought, resource scarcity and pressure on natural resources urge us to fundamentally change the way we design, construct and maintain our built environment. Players in the construction sector need to adapt to these new complexities in order to remain or indeed become future-proof.

According to the UN, worldwide population growth is expected to continue until the year 2100, when it will have increased to a number between 9.4 and 12.7 billion people. Growth rates will differ widely between regions. Due to ageing of the population and lower birthrates, it is estimated that the European population will start to decrease after 2050. Urbanization will further increase. About 68% of the world's population will live in urban areas by 2050, which is an increase of 13% in relation to 2018 figures.[4]

Buildings account for around 39% of global carbon emissions. We need to include embodied carbon in our calculations as it represents a significant part of the total carbon footprint of buildings.[5] The World Green Building Council estimates that at least 11% of the global carbon emissions have been overlooked because embodied carbon was not calculated. Especially as new construction is expected to double the world's building stock by 2060, it is essential to include embodied carbon. In order to meet the climate goals as set in the Paris Agreement, energy intensity per square meter must decrease with 30% by 2030 (compared to 2015).[6]

The effects of climate change are already being felt in cities around the world. Extreme weather conditions such as increasing frequency of cyclones, changing precipitation patterns and rising sea levels increase the vulnerability of densely populated areas. Failure to act will result in an increase of displaced populations and fatalities caused by climate change.[7]

The construction sector has taken the first steps in the transition towards a circular economy and has started moving from incremental to systemic changes. However, this change is not progressing at the required pace. The Circularity Gap Report 2020 revealed that only 8.6% of the global economy is circular, which makes a compelling case for the need to invest in the required systemic changes. [8]

The exponential increase in prosperity across emerging economies also demands transformational change. Historically, increased income is associated with changes in dietary demands (more proteins).[9] At the same time, the use of biobased materials as an alternative for non-renewable oil-based resources is expected to grow. These developments will increase the competition for arable land for food, feed, biofuels and biobased materials.

OPPORTUNITY

The construction industry is a growing sector. Revenue is expected to reach USD $15 trillion by 2025, expanding each year by 3.6% between 2018 and 2022.[10]

Compared to other sectors, however, productivity in the construction sector is relatively low. Where on a global level, productivity increases by 2.8% per year on average, the construction sector is behind with an average yearly growth of 1%.[10]

The increasing global demand for urban housing is favorable for business. The demand is not only for new buildings but, more prominently, for renovation of the existing stock to make it future-proof. This includes energy neutrality, health and safety of materials and indoor climate, circularity and sustainability in general.

This continued demand for future-proof built assets can only be met if the sector is prepared for the fundamental changes it requires: restructuring of traditional business processes, integration across the value chain, diversification and coping with increasingly complex environments and pressure on resources.

Increased data sharing and use among actors in the construction value chain is expected to improve efficiency and decision making, leading to direct financial benefits. When the sector changes its way of working and embraces digitalization, the vast value that is present in big data can be unlocked. For example, a recent study estimated that in the UK alone, big data contributes around £50 billion in direct, indirect and induced impacts a year at present.[11] In fact, between 2012-15, big data contributed more to the UK's GDP than R&D.[12] The Centre for Digital Built Britain estimated that:

"Greater data sharing could release an additional £7bn per year of benefits across the UK infrastructure sectors, equivalent to 25% of total spend."[13]

BUSINESS CONTINUITY

The developments impacting the construction sector in the coming decades, such as projected growth rates, resource scarcity and climate change, demonstrate that the built environment will be subject to disruption. In order to cope with these transformations, players across the value chain will have to prepare and adjust. Beyond merely ensuring business continuity, these adjustments can also allow for positive contributions to a future-proof and sustainable built environment.[14]

1.2. SUSTAINABILITY AS A DRIVER FOR BUSINESS CONTINUITY

Ensured business continuity requires us to carefully consider the transition towards a sustainable future-proof construction sector. In line with existing materiality analysis frameworks such as the Natural Capital Protocol, five drivers for business continuity are identified. [23] Figure 2 contains the generic description of the individual aspects of business continuity. The following sections demonstrate the impact and importance of sustainable practices in light of business continuity in the construction industry.

Figure 2: The five pillars of business continuity

OPERATIONS The principal operations of an organization: design, service, production, R&D, etc.

COMPLIANCE The extent to which the operations and activities of an organization may trigger a legal process or liability; compliance to legislation, licenses, frameworks such as BREEAM, etc.

BRAND AND IMAGE The extent to which the operations and activities of an organization may affect the product portfolio, company image or relationship with customers and other stakeholders (e.g. changing customer preferences).

FINANCE The extent to which the operations and activities of an organization can influence "cost of capital" or access to capital, investor interest or insurance conditions.

SOCIETY The extent to which the operations and activities of an organization may influence the local environment i.e. the relation between an organization and society.

OPERATIONS

The construction sector uses large amounts of materials and energy to develop, operate and demolish buildings. Optimization of resource use throughout the construction value chain and asset life cycle phases is an important starting point to improve the impact of operations.[16]

Significant improvements in sustainability impacts will require changes on a fundamental level. For example how sustainability is integrated in design and construction or how value chains are configured in the most resource-efficient manner.

Collaboration with value chain partners becomes necessary to improve resource security, improve value chain transparency and to optimize production (for example, production of prefabricated components and building products). Automated performance information collection can improve decision making processes. It enables companies to include the complexity of the life cycle and value chains into integrated business decisions. Client and public perception of social and environmental impact drive a need for increased corporate transparency and accountability- and vice versa.

COMPLIANCE

Compliance with local legislation is a prerequisite for business continuity. However, there are some additional aspects surrounding the issue of compliance that require consideration. Certification schemes such as BREEAM, LEED, GRESB and Well Building standard currently influence the value of assets: investors and developers increasingly demand compliance with such standards.[17] Emissions of CO_2, other GHG gases, nitrogen or Volatile Organic Compounds (VOCs) as a direct or indirect result of construction activities are in many cases bound by specific regulatory thresholds.[18] An example recently occurred in the Netherlands, when failure to comply with European legislation on nitrogen emissions led the construction sector to almost grind to a halt.[19]

BRAND AND IMAGE

Consumers and clients increasingly require companies to demonstrate sustainable and transparent practices and to continuously improve on their corporate social responsibility. Meaningful transparency and communication regarding sustainable and circular practices require sharing of information along the value chain and life cycles. Responsibility and accountability can positively contribute to a brand image if corporate communication is supported by robust and reliable data. Conversely, a safety incident or the disclosure of unverifiable performance information can cause serious reputational damage.[20]

ACCESS TO FINANCE

Access to finance and the cost of capital are already influenced by the disclosure of quality non-financial information. Investors and shareholders are increasingly treating environmental, social and governance information as a center point investment, financial decisions and pricing of assets.[21] A company's ability to substantiate their social and environmental impacts through their core business processes, as well as their Corporate Social Responsibility (CSR) efforts, has become an important component for investors' and subsidy providers' risk assessments. The financial health of organizations in the construction sector therefore increasingly depends on the availability and quality of non-financial performance information. Given the complexity and scale of the construction sector as well as individual organizations, digitalization is becoming a vital tool to support the collection, analysis and maintenance of these information flows.[22]

SOCIETY

Citizens and consumers are the beneficiaries of a healthy and safe built environment. Production facilities, utility assets and construction sites can have an impact on the quality of the built and natural environment. Air, water, noise and light pollution may seriously impact the perceived scenic value of an area, especially in densely populated areas. The general public increasingly demands sustainable practices and social responsibility when it comes to the location, design, construction and subsequent use of assets.[23] Citizens are crucial stakeholders who want to understand what companies are doing in their neighborhoods and how their living environment and wellbeing are impacted. Public perception of a company's core activities and care for the environment is therefore a fundamental part of their 'license to operate'.

ESG Digital Transformation

How Arcadis harnesses digital transformation to improve business performance

THE VALUE CASE

Recent data shows that stakeholders across the value chain, including investors, employees and customers, place a higher value on organizations that embed Environmental, Social and Governance (ESG) accountability into their core beliefs. ESG digital transformation can increase operational efficiency, reduce risk, create safer work environments and enhance business performance. The days of manually managing ESG programs through paper, spreadsheets and shared data spaces are therefore long past. The digital transformation of ESG management programs, processes and practices is a proven accelerator in value creation and business performance.

THE JOURNEY

Creating ESG value can often be a challenging process to manage as organizations define, measure and report on ESG components most relevant to their business. The ESG digital transformation journey is different for each organization depending on that organization's ESG and digital experience and maturity. The journey to ESG success starts with one fundamental question — what ESG indicators will be used and how will they be managed for both internal and external reporting purposes?

The next step is the "how". Organizing the management of an ESG strategy, and subsequently executing this strategy, can bring with it a range of complexities. In order to maintain a successful ESG program, Arcadis has identified five key phases to guide management of a program: Identify, Collect, Manage, Measure and Report.

By applying digital transformation practices across this full life cycle, ESG program management becomes far more manageable. Utilizing digital tools also allows for greater organizational transparency in business practices. Whether managing just a few complex ESG metrics or many with a broad range of data types and complexity, the days of manually managing ESG programs through spreadsheets are long past.

IN PRACTICE

Arcadis starts by partnering with clients to articulate their long-term ESG management strategy and program roadmap. Based on that shared roadmap and a thorough analysis of the client's business objectives, digital system(s), organization and process requirements, digital ESG solutions are designed, implemented, deployed and sustained.

Arcadis Digital EHS & Sustainability Center of Excellence brings seasoned subject matter experts, technologists and management consultants with extensive experience across organizations of all types, from local government agencies to global public companies.

ARCADIS Design & Consultancy for natural and built assets

The days of manually managing ESG programs through paper, spreadsheets and shared data spaces are long past.

The road to digital transformation can be a challenging proposition — financially, emotionally and organizationally.

"These solutions allow clients to make integrated and proactive data-driven decisions that reduce environmental impact or compliance risks and drive safer, higher performing operations and products"

Vijay Gudivaka, Arcadis Executive Director and Global Director for Digital EHS & Sustainability business

2 Sector characteristics that challenge progress

2 The construction sector: intrinsic challenges

The sky-high expectations regarding the benefits of digitalization can only materialize under very specific cultural, financial and institutional conditions, which are not always met in the construction sector.

A SUBSTANTIAL SECTOR

The construction sector is one of the largest economic structures in the world with estimated annual spending of USD $10 trillion every year on construction-related goods and service.[10] Market value is expected to continue to grow 4.2% annually between 2018 and 2023.

A GLOBAL, SILOED AND FRAGMENTED INDUSTRY

The construction sector can be characterized as a fragmented industry.[10] The European Commission estimates that up to 98% of the construction value chain is composed of micro, small and medium-sized enterprises. The typical construction project involves a multitude of independent manufacturers, subcontractors and suppliers who are responsible for individual life-cycle phases and activities. Each of these phases, for instance design, procurement or construction is affected by different stakeholders at different moments in time. This practice of project-based work limits knowledge transfer among actors or life cycle phases, resulting in limited transparency, productivity and resource efficiency.

CULTURAL CHARACTERISTICS

The construction sector is often described as a traditional industry,[24, 25] where business processes are linear, tasks are fragmented and organizational culture is generally averse to risk and change. Vennstrom et al. distinguish three types of barriers that limit the sector's ability to adopt change and cause actors to remain competition driven and risk-averse: attitudinal, industrial and institutional.[25]

Attitudinal barriers refer to the characteristics of an individual organization's culture. It is found that in the construction industry, a strong focus on project delivery incentivizes the prioritization of short term project goals, such as budget, over client results, process improvements or innovation.

Industrial barriers refer to the organization of the construction process. Generally speaking, competition-driven procurement practices de-incentivize cooperation between actors and therefore perpetuate a fragmented, top-down approach to construction.

Institutional barriers refer to the highly regulated, traditional procurement processes in the construction industry, which lead to profit-protection attitudes.

Vennstrom et al's study demonstrates that, from a client perspective, attitudinal barriers are perceived as the most critical factors that inhibit change.

OPERATING WITH TIGHT MARGINS

Margins in the construction industry have historically been small. The operating margin from construction activities was 5.5% of sales in 2018 while non-construction activities averaged 8.3%.[26] Chinese, American and European groups recorded net income margins between 3% and 5%. These low margins could constrain the industry to invest in R&D and digitalization.

LAGGING PRODUCTIVITY AND EFFICIENCY

According to McKinsey, construction firms are currently struggling to find the workforce that they need to increase their productivity by even 1%. The overall growth of labor productivity in other sectors is significantly higher, generally up to 4%.[10]

While productivity levels vary greatly along the construction value chain, as well as between regions, a number of common factors can be identified that cause these low productivity rates. MGI defines external, sector-wide and firm-level factors as root causes.

External factors include regulation, high levels of dependency on public investment and the increasing complexity of the sector. MGI lists sector dynamics, fragmentation, contractual incentives and suboptimal procurement criteria as **sector-wide** factors. **At firm-level**, the lack of investment capacity causes operational failures, lack of standardization as well as limited investment in digitalization, innovation and labor force skills.

LIMITED INNOVATION CAPACITY

Siloed working, fragmentation of responsibilities and ownership may result in a slower or narrow uptake of innovation. The European Commission asserts that fragmentation leads to limited innovation activity, low rates of technological adoption and decreasing efficiency. [27] Evidence suggests that most innovation in the construction industry takes place at a project level.[28] Limited (real time) information exchange, lack of standardization, competing interests and investment capacity all hamper the required integration and collaboration between actors and life cycle phases thus inhibiting the sustainability performance improvement of future designs.

BOX: 1 DIGITALIZATION IN CONSTRUCTION

Digital technologies used in the construction sector include general purpose technologies relating to management and governance, as well as very specific digital building technologies that support technical activities relating to design, engineering, construction and maintenance.

Meuer et al.'s typology of digital building technologies helps structure our evaluation of the technological landscape in the construction sector. In this framework, technologies are categorized along two axes: cyber-physical technologies versus software-based technologies and complementary technologies[29] versus platform technologies. An overview of digital building technologies is provided in Figure 3.

To develop a view of current developments and innovations in digital building technologies, Meuer et al.'s framework was applied to the Technology Periodic Table developed by Arcadis and Accenture/Carlo Ratti Associatti. [30]

The impacts and level of adoption vary within the four types of building technologies. In general, technological complexity increases with the shift from software-based technologies to cyber-physical technologies and from complementary to platform technologies.

Cyber-physical technologies such as GIS, laser scanning and drones are often independently applied, rather than interconnected through an interface.

Cyber-physical complementary technologies frequently draw on general-purpose technologies to connect multiple devices and recognize their physical environment. Because those technologies are designed to intervene and adapt to a building's physical properties, they are highly sophisticated technologies.

Software-based complementary technologies account for a comparably low technological complexity as they do not rely on large database architectures and rarely draw on general-purpose digital technologies. Because they are stand-alone and task-specific, they rarely require substantive changes in the organization and are thus easily implemented and do not demand alignment with partners, suppliers or customers. Moreover, the economic benefits are readily apparent and explain why these technologies are already widely applied in the building industry.

Software-based platform technologies can be found in all life cycle phases of a building and all industry actors are potential technology users. They primarily foster transparency, thus directly addressing a major barrier for modernization in the building industry. Moreover, those technologies often constitute the first step towards enabling sustainability contribution of other digital building technologies.

Figure 3: Typology of digital building technology landscape

Platform technologies have the potential to unlock enormous benefits for the construction life cycle, as well as governance and decision-making in the construction sector.

A collaborative study by Arcadis, Accenture and Carlo Ratti Associatti (CRA), outlines trends that are expected to significantly affect the built environment.

Each of these trends is enabled through applying a specific combination of (cyber-) physical, software-based and platform technologies.

The application of technologies such as machine learning, artificial intelligence and big data, for example, increasingly enables actors in the construction value chain to optimize key business processes relating to finance, communication and administrative tasks.[1, 31]

The transition towards the circular economy could also be supported by a combination of technologies such as the Internet of Things, Big data, sensors, robotics and 5G networks.

3 The future-proof construction sector

3 The future-proof construction sector

Figure 4: Characteristics of the sustainable and future-proof construction sector

A future-proof construction sector needs to balance increasing its productivity to meet housing demands while respecting the planetary boundaries. It is a sector that focuses on resource optimization and circular operations to lower its impact and to guarantee resource security. Already, increased effort to link the different phases of the life cycle, to share information for resource optimization (e.g. energy and material use) throughout the entire life cycle can be observed.

The sector is expected to further adapt to changing consumer and client demands in relation to sustainability. Increasing transparancy by disclosing information about sustainability and operational performance helps companies to get access to external funding and investments. Transparancy is also essential for branding and the company image. Frontrunners are exploring new ways to include sustainability in their decision-making process.

Before long, it is expected that sustainability considerations will affect all business decisions and that it will take the center stage in business strategies.

In the past few decades, digitalization has proven to be a powerful enabler for change. With the ever more complex challenges at hand in the near future, digitalization has become an even more relevant enabler for business continuity.

3.1. TOWARDS AN INNOVATION-ORIENTED CULTURE

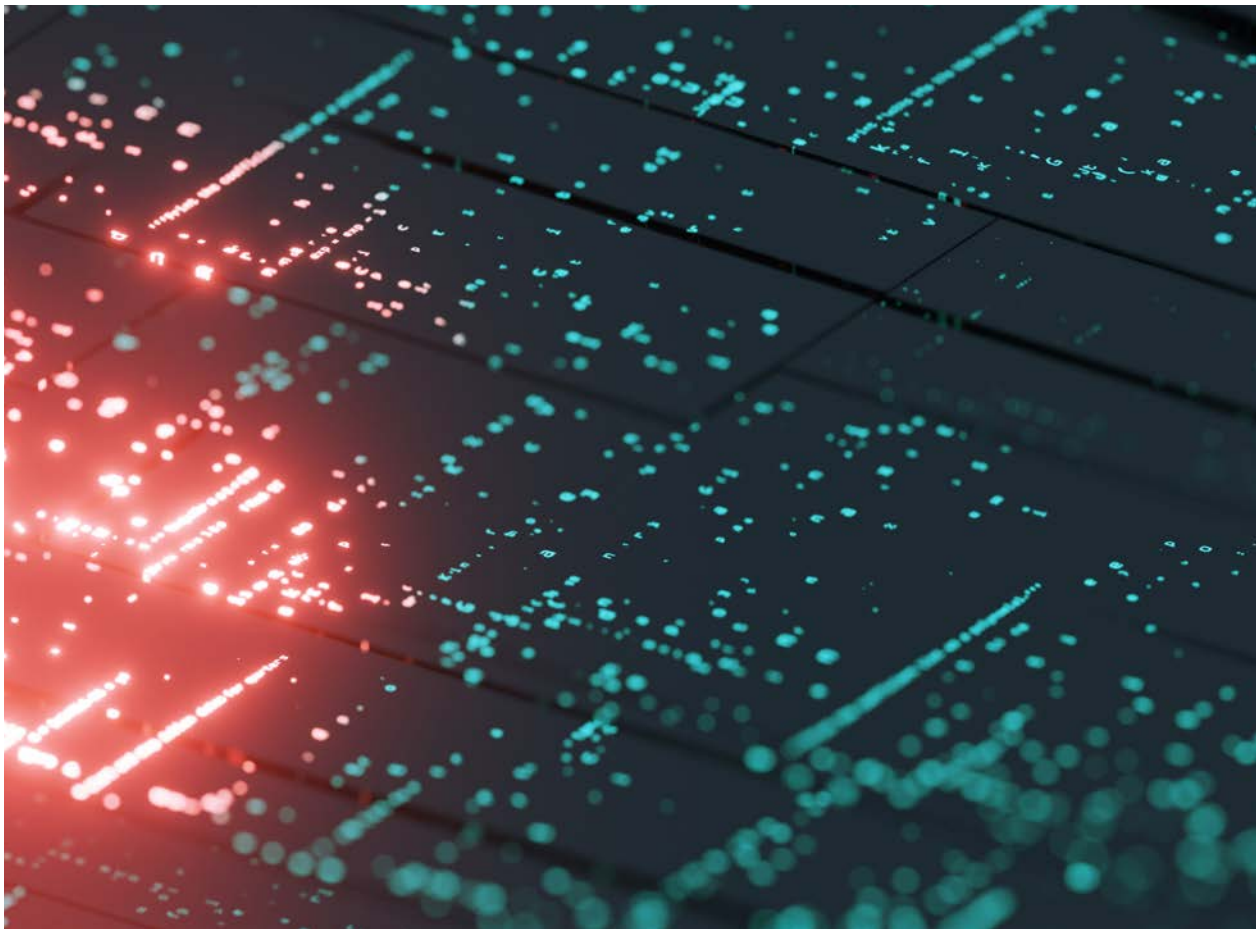
To embrace digitalization as a key enabler for sustainability, the sector will need to find ways to accelerate innovation, not only technological innovation, but also at process and operational level.

Actors in the construction sector will need to be able to cope with and manage internal and external changes within and among organizations that collaborate in the value chain or life cycle. As has been demonstrated throughout this report, effecting changes is especially complicated given the sector's nature and current practices: the strong focus on individual and often unique projects, with a unique set of stakeholders and unique (locational) circumstances inhibits the organizational or inter-organizational change required to improve sustainable practices.

Bengtsson et al. offer the concept of receptiveness to change as contributing factors to implementation of inter-organizational innovations.[28] These aspects are all related to the organizational cultures of collaborating companies. Companies need to address elements such as demonstrating ownership and leadership, the ability to define clear objectives and setting coherent policies, initiating effective professional relations and networks, and facilitating a supportive culture. Companies need address these aspect both as an organization as well as within specific projects.

A future-proof, sustainable and healthy construction sector depends on the ability of actors in the value chain to connect, harvest and utilize information about the complexity of sustainability.

To shape this future, digitalization is an essential enabler as is explained in more detail in section 3.2.



3.2. HOW DIGITALIZATION ENABLES A SUSTAINABLE AND FUTURE-PROOF CONSTRUCTION SECTOR

Digital solutions contribute to all areas of business continuity by improving the ability to understand, analyze and optimize sustainability performance on the level of individual projects as well as organizations or entire value chains. This insight is needed for substantiated strategic and operational decision making and to provide the required (performance) information as part of compliance mechanisms or for access to finance. In addition, it enables companies and the sector to demonstrate the results of their efforts to become more sustainable.

WHY INCREASING COMPLEXITY REQUIRES DIGITAL DATA DRIVEN SOLUTIONS

Digitalization and data-driven design allow us to cope with the increasing complexity of our built environment. Fitting in new or renovation of existing assets in dense urban areas requires us to take into account an increasing amount of context information, such as:

- location of utility infrastructure;
- the capacity of existing constructions;
- disruption of traffic flows;
- health and safety of the general public;
- changing weather patterns that may affect drainage requirements, soil conditions, heat stress;
- biodiversity;
- life cycle analyses;
- protected sites and cultural heritage;
- requirements for building materials;
- pollution standards.

An integral evaluation of all these variables has become vital for the success of design and execution of any construction project.

Sustainable or circular design principles, such as limited extraction of raw materials, re-use and sustainable component production, often introduce new requirements. Sustainable practices require close collaboration along the construction value chain and among asset life cycles.

Information exchange and collaboration between potentially large numbers of actors therefore becomes vital to developing sustainable solutions.

Digital platforms to support collaboration and information exchange allow us to integrate sustainable practices into our decision making throughout the value chain and prevent duplication of efforts between actors or life cycle stages.

Optimization also includes automation of supporting business processes or administrative tasks, which lowers costs and allows skilled employees to focus on their core activities. A 2016 survey among 397 companies in the construction sector showed that companies expected a revenue growth of 2,7% annually due to digitalization.[32]

> It is astounding to realize how much digitalization benefits organizations to become more sustainable.
>
> **Paul Camuti,**
> Trane Technologies, Executive vice president and chief technology and strategy officer.

Optimizing sustainability through digital design

How Autodesk's digital tools are enhancing design and construction processes to drive sustainable outcomes

THE CHALLENGE

Although the construction industry is realizing the importance of integrating sustainability into business models, this integration often manifests through top-down sustainability reports and high level, organization-wide commitments that do not always translate to the project level. There are innovative digital design and construction technologies that enable companies to meet and exceed sustainability goals, but there is a need to rapidly expand and accelerate widespread adoption at the project level across the industry. Helping make the connection between organization-wide sustainability goals and innovative digital design and construction technologies, while identifying and overcoming barriers to their adoption at the project level, is key to driving sustainability successes across the industry.

THE JOURNEY

The most difficult step in an organization's journey toward digitalization is getting started. There may be resistance from stakeholders who perceive such digital tools as an unnecessary disruption to their operational business model, or who do not yet equate sustainability with long-term co-benefits for all stakeholders, like improved efficiency and coordination, or reduced risk, errors, rework and waste. Autodesk recognizes the importance of change management when encouraging designers and construction professionals to use their digital tools. Autodesk meets the customer where they are on their digititization journey, and in partnership, helps customers progress towards their sustainability goals. Crucially, this includes introducing sustainability as a foundational principle on projects, rather than providing a set of specific 'sustainable solutions'. Autodesk understands that providing data and insights informs decision making and is critical to meeting sustainability goals, both at an organization-wide level and on a project level. Whether it is equipping architects with insight for early stage energy analysis to quickly model the impacts of design decisions on the overall energy consumption of each project, or construction professionals with the Embodied Carbon in Construction Calculator to visualize the embodied carbon of materials choices, Autodesk is striving to make climate-smart decision-making quick, easy, accurate and accessible to all.

IN PRACTICE

A great example of the transformative role that software can have in project design is Autodesk's Generative Design process, which explores all the possible permutations of a solution according to goals and intentions input by a designer, and quickly generates thousands of options to determine the optimum design for their needs. For example, this was used in the design of neighbourhoods to optimize affordability, energy efficiency and neighbourhood safety. This digital technology provides a huge opportunity to more deeply understand and utilize the "hidden efficiencies" at the early stages of design.

Autodesk makes software for people who make things. If you've ever driven a high-performance car, admired a towering skyscraper, used a smartphone or watched a great film, chances are you've experienced what millions of Autodesk customers are doing with their software. At Autodesk, sustainability is about equipping innovators with the tools and knowledge to use energy and materials more productively, design and make for health and resilience and learn new skills to adapt and prosper in an ever changing world.

AUTODESK

The creation of digital workflows allows stakeholders to collaborate in entirely new ways.

The opportunity for the greatest impact on a project happens early in the design process, during the critical decision-making stages.

"The sophistication of today's technology is empowering innovators to achieve the 'new possible,' enabling us to better solve the complexities of sustainability."

-Lynelle Preston Cameron
Autodesk Chief Sustainability Officer

TRANSPARENCY AND ACCOUNTABILITY ALONG THE VALUE CHAIN

Data driven and science-based approaches to the collection, management and reporting of sustainability performance information allows organizations to effectively and continuously monitor their operations, prevent incidents, improve decision making and target interventions for performance improvement. A robust information management approach helps companies demonstrate compliance, assess risks, communicate transparently and build trust.[13]

Digitalization generally enables the collection, processing, analysis and disclosure of large and complex sets of data. It is therefore perceived as a key enabler to improve transparency on several levels, including inter-organizational (along the value chain) and public disclosure.

The disclosure of non-financial information regarding organizations' environmental, social and governance outcomes has become an industry standard in recent years. External actors such as regulatory agencies, investors and the general public (i.e. end users and consumers) increasingly require accountability with regards to corporate social and environmental responsibility. Transparent reporting has become vital for business continuity aspects such as access to and cost of finance and company or sector image.

Digital data management tools allow organizations to monitor, evaluate and disclose these specific, detailed and often complex non-financial metrics to meet those needs.

A truly sustainable value chain requires a deep understanding of and insight into the production and legacy of resources, as well as a complete and reliable assessment of good governance, social impact, labor circumstances and environmental management. Digitalization enables actors along the value chain to report transparently, demonstrate accountability and manage risks more effectively.

Even without full transparency of the value chain - knowing where your resources originate from and under what circumstances they are manufactured - traceability is important. Digital solutions enable traceability through the various life cycle stages of materials and products. In the past few decades, the use of paperwork and tags such as Radio Frequency Identification (RFID) helped to follow products (partly) through the value chain. Emerging blockchain technologies aim to create a digital tag that helps trace the resource through transactions and conversions in the value chain.

DIGITALIZATION AS A DRIVER FOR SUSTAINABLE PRODUCTIVITY AND INCREASED EFFICIENCY

One of the main challenges for the coming decades is how the construction sector will balance increased productivity with a respect for our planetary boundaries. The speed of expanding, refurbishing, and renovating the existing building stock needs to increase to provide housing for the continuously growing urban population.

MGI calculates that productivity will increase 6-10% due to on-site executions, and 14-15% by infusing technology and innovation.[10] Productivity will also increase as design is based on an abundance of spatial, social, demographic, city planning, environmental, climate related and resource data. This will help prevent unforeseen issues that can slow down construction.

Automation and standardization of design and construction is expected to increase efficiency and on-site construction time as prefabricated components can be easily assembled on-site with limited manual labor. Applications that help construction managers oversee the entire building process can help to prevent issues, optimize planning and resource use. Blockchain technologies and 'internet of materials' (i.e. a cloud-based platform for material exchange) will support design and construction companies in their efforts in their efforts to increase resource efficiency and productivity at the same time.

DIGITALLY ENABLED RESOURCE OPTIMIZATION

Driven by increasing resource scarcity and GHG reduction targets, the circular economy will develop at a rapid pace. Organizations and countries have set targets such as 100% circular economy in 2050 (e.g. the Netherlands).[33]

In the circular economy, companies will need to better understand how resources flow through their operations and apply radical changes to their operations to ensure their continued availability at a realistic cost. Reduction targets such as 100% for carbon emissions related to operations, and embodied carbon, will further drive the need for resource optimization.

Digital solutions will help organizations in tracing materials throughout the life cycle of a building. Buildings will as such become a temporary storage of materials. The residual value of an asset at end of life will hence not be zero, but at least the value of its embodied materials. Digital solutions will allow for a tracking and tracing approach for the quantity and quality of materials enclosed in construction, which will in turn enable their reuse.

Digitalization of the design process, using 3D to 6D modelling or digital twins, helps to optimize the resource use. A digital twin is a computer model which mirrors and simulates a buildings and infrastructure and the surrounding environment. Digital twin models can be developed for whole areas such as Western Sydney.[34] or even at national level, as now is being developed for the UK.[35] Digital twin models can help to organize data and make it accessible to optimize constructions and infrastructure. They can be developed for built constructions and infrastructure and support the redesign and renovation projects. Digital twins can also be used to share data with multiple stakeholders and with defined levels of access, to inform better decisions about how to build and manage infrastructure. In short: digital twins help to better understand what the optimal and efficient solutions are, and to compare alternatives without having to build anything.

Digitalization also enables predictive maintenance, which is designed to determine the condition of operational equipment in buildings to estimate when maintenance should be performed. This helps to optimally schedule corrective maintenance and prevent unexpected failures. Research conducted by Deloitte in 2017 found that proactive maintenance increases uptime by 10-20% in machines and equipment while reducing overall maintenance costs by 5-10%. [36]

Low-carbon, circular materials represent the future of construction, digitalisation brings transparency, enhances efficiency and clearly adds value to these materials.

David Blomquist,
Director of Digital Business, Stora Enso

The benefits of an information driven start

How Bryden Wood radically changed the design process

THE CHALLENGE

Bryden wood challenged itself to redesign the construction process using an abundance of information and applying the principles of the manufacturing industries. The aim was to make the process more efficient and less prone to errors delivering better results and more sustainable construction.

THE JOURNEY

If you stop looking at the differences between buildings, you can focus on the similarities and can look at them from a manufacturing perspective. That thought is what has driven Bryden Wood to invest in information management and explore the opportunities of digitalization. Their Platform approach to Design for Manufacture and Assembly (P-DfMA) is based on a vast collection of information and is combined with readily available materials to deliver a broad range of building products without limiting design ambitions. Over the past 25 years, Bryden Wood have developed their approach and learned a lot about what types of information you need to really understand the needs of the client. With their own construction testing facility, they can rapidly test materials and construction techniques that have been virtually tested first. This rigorous preparation - a combination of digital design and physical pilot testing - helps to make the actual construction much more efficient and predictable, and therefore delivers significant reductions in cost and time.

IN PRACTICE

Bryden Wood demonstrate to clients that starting with a good information-based understanding of the client challenge leads to better risk management as they create an evidence base for design and construction and a better ROI.

Their own organizational processes have become digitalized and information-based. They work closely together with their clients in multidisciplinary teams, even sometimes as a physical joint team in the Bryden Wood offices. The company attracts and actively seeks new employees with additional digital skills complementary to design, construction and engineering skills.

Bryden Wood is an international technology-led design company made up of over 250 architects, analysts, software coders, engineers and industrial designers. Bryden Wood's vision is to close the gap between construction and manufacturing, to create highly productive, digitally led solutions, which result in the delivery of high-quality sustainable architecture.

Bryden Wood

Invest in a good, information-driven start of the process. This means that you will have to stop and (re) think before you start building.

Rethink your design process to become a multidisciplinary co-creative team effort.

"Digital tools and additional information enable human thinking"

Jaimie Johnston, Head of global systems

DIGITALLY ENABLED INCLUSION OF END-CONSUMER AND CITIZEN DEMANDS

Consumers and citizens increasingly demand from the construction sector the reduction of environmental and social impacts. Local governments and other public sector organizations specifically demand more sustainable and socially responsible projects.

Digitalization and access to information have had a direct role in shaping sustainability demands from consumers. Innovative applications that help consumers make their own floor design, select materials or help them to customize furniture are quickly becoming standard in the design process, and consumers are able to experience the outcomes of their choices in the design phase.

More passively, smart use of interactions and behavior of consumers within specific dwellings will increasingly be the basis for new projects. Information will be collected through a mix of consumer applications, big data mining and specific sensors. Information about preferences and consumer trends will be combined with data about spatial planning, demographic trends, city climate, etc.

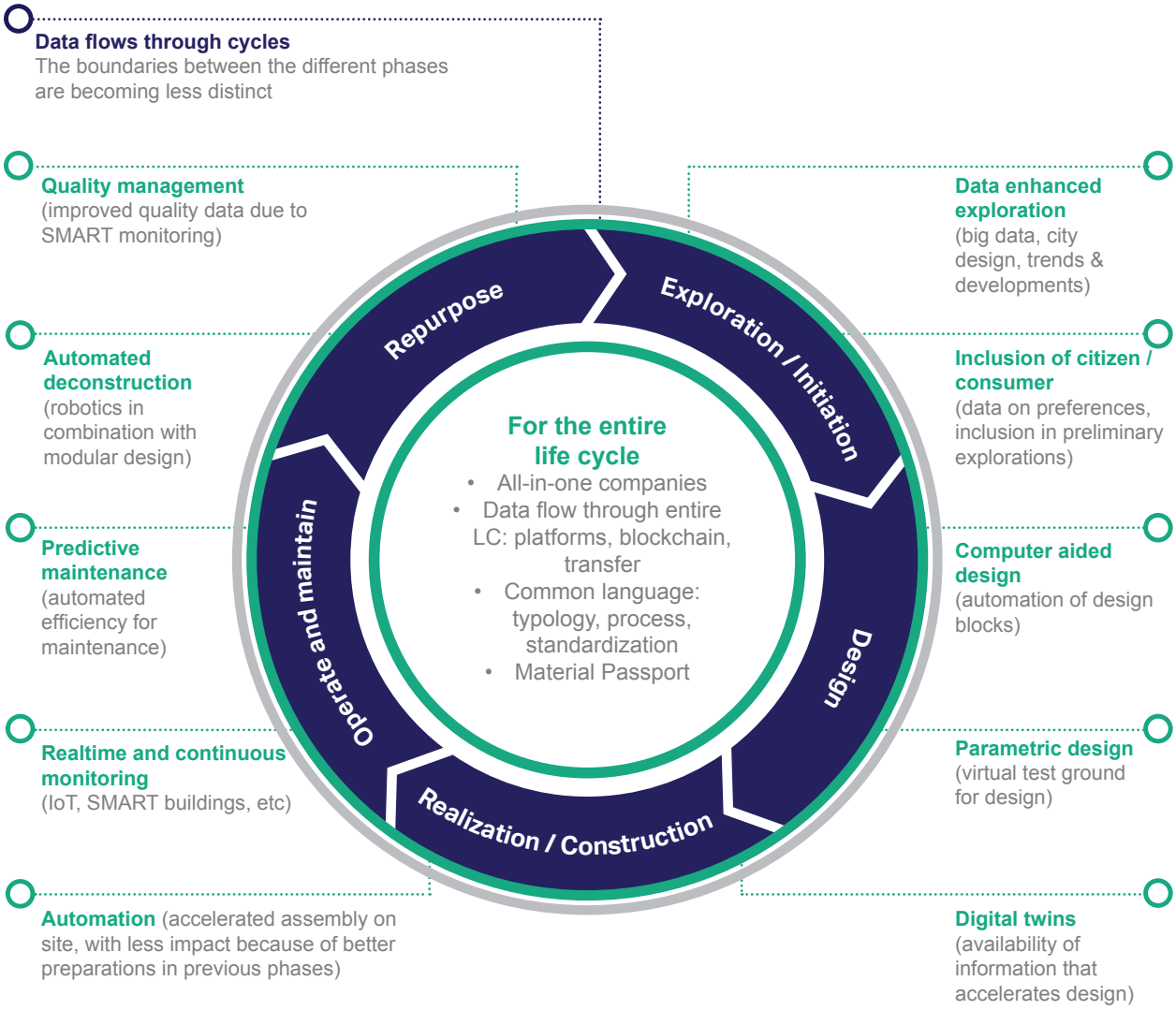
The 'relation' between a building and its user may change due to interfaces between mobile devises and building applications. Therefore users are more aware of the sustainability performance of a building.

Citizens are 'in sync' with their working and living environment. Part of the manual effort of today will be replaced by an active Internet of Things in which appliances automatically communicate with each other. For example, the fridge may communicate with your mobile phone to list all groceries that are needed for tonight, based on a recipe of your choice. Your car communicates its location to your house, so the temperature automatically increases to an optimum when you arrive. These services will be integrated in the design and construction of buildings.

HOW DIGITALIZATION ENABLES CONNECTION OF LIFE CYCLE PHASES

The development of sustainable assets requires a concerted effort and alignment along the entire value chain. Individual project partners need to broaden their scope to include multiple phases or even the entire life cycle. Deliberate action is needed to create efficiency and to transfer knowledge from one phase to the next. Information about design, construction, maintenance and disassembly should be shared amongst partners in the life cycle so optimization of resources can be achieved (see figure 5). This requires exchange of robust metadata on for example origins, environmental impact, and functional characteristics of materials and elements.

Figure 5: Conceptualization of information flows through life cycle phases



New business models are emerging that incorporate or connect several stages of the life cycle.[37] We are already seeing some companies spanning several phases of the life cycle. These companies manage the design, construction, maintenance and deconstruction of buildings (nowadays mostly residential homes). Business models like these are examples of a revolution that requires digital solutions that can manage the resource flow through organizations or through the entire value chain. Companies also need to ask themselves, what will become available at the end of the use life of the building and how can these companies reuse these materials?

Other sectors such as the financial sector play a role in the life cycle and should be connected. Financial mechanisms, such as mortgages and new forms of ownership, are vital for new innovative solutions and underpin the necessity of increased cross-sectoral life cycle integration. Collaboration and exchange of best practice with other sectors (such as infrastructure and city planning) will also increase with this shift.

We need to learn more from each other. This will help to accelerate our transition to a sustainable digital construction sector.

Sander Beeks,
Business support Madaster

Data flows that include climate related risks, demographic trends, material innovations and resource management will be integrated in cross-sectoral platforms that provide big data that help the construction sector to better design, plan, execute and operate assets. This requires a 'digital bridge' between the information management systems of the various actors.

The digital connection will create shared value. Sharing information may change the value of information. Information that needs to be transferred to the next life cycle phase could become a valuable asset as compared to the current situation in which each company starts from scratch, gathering its own information. The balance between proprietary and open source information is likely to shift. We are tackling global sustainability challenges, which need a collective effort. Sharing information is elemental in this collective effort.

DIGITALIZATION IMPROVES SUSTAINABILITY-DRIVEN DECISION-MAKING

Sustainability and circular economy are too often viewed as too complex or abstract to incorporate in our decision-making processes. Companies nevertheless will need to integrate it into their decisions as sustainability increasingly becomes a key consideration to address in operations, compliance, branding, access to finance and their relation to society.

Sustainability and circular economy are only just starting to be integrated in management information systems. Performance data (both meta and specific) needs to be collected, governed, monitored, weighed, and analyzed. Examples of performance data are: data on sourcing of materials, the sustainability performance of designs, information about the sustainability of the production process, and information about the performance of buildings, energy management and embedded material stock.

At the design phase the availability of digital design tools (3D and 4D, CAD, etc.) helps organizations to understand the implications of decisions. Decisions can be based on a complete set of information that is assembled and stored in document management platforms such as BIM. Material passports will help companies to better forecast the availability and quality of materials and help companies to make better design and construction decisions.

One Click LCA is an automated life cycle assessment software that helps companies to calculate and reduce the environmental impacts of buildings and infrastructure projects, products and portfolios. Access to data related to the products feed the decision of the project and the design that consequently inform the portfolio.

These design tools provide information on products and materials starting at the concept/ design phase to help making the right decisions from the very start of a project. For example One Click: LCA gives information on whole life cycle assessment, on costs from all life cycle stages, on the carbon footprint of a building and helps design more circular buildings.

Targeted (semi-)automated data collection and the addition of open or external data sources to decision support systems (e.g. risk management and financial management systems) will improve a company's ability to anticipate risks, seize opportunities, improve overall performance, improve product quality and create additional value. In the end, it helps prevent financial losses.[38] Information about non-financial performance will be integrated in the decision process and data driven forecasts will enable decision makers to adopt a longer-term perspective. Information may be sourced from or can be generated by:

- historical performance data;
- non-financial information about environmental, social and governance outcomes;
- open data;
- performance data from continuous and automated monitoring of production or construction sites. This supports decision making about maintenance and end-of-life reuse of materials;
- technologies such as 6D or 7D models, AR, and digital twins will enable designers to better understand the outcomes of their designs and how it will operate in the local environment.

BOX: 2
ON TRANSFORMATIONS

Both sustainability and digitalization require a fundamental transformation of the construction value chain and processes. Transformations, or transitions, are generally associated with destabilization because they seem to happen irregularly, dynamically, and are based on a vast number of variables.

Successfully navigating transitions requires an understanding of these dynamics.

Drift for Transition, a research institute of the Erasmus University, has developed a framework that helps to understand the dynamics of transitions, depicted in the X-curve below.[39]

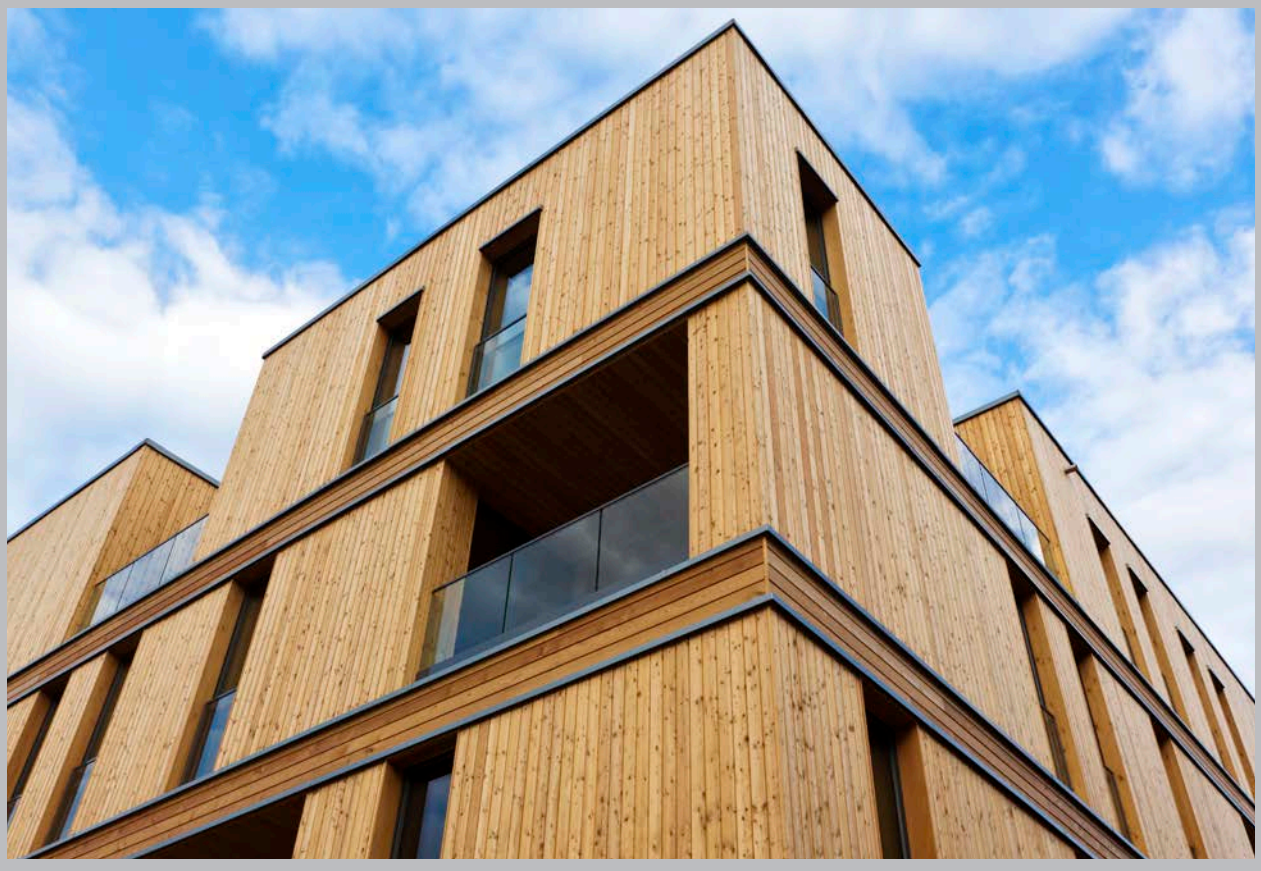
The X-curve (Figure 6) describes two systems:

1. The established regime. This is the status quo represented by large incumbents, that have been operating in a certain way for a long time. This concerns both public and private sector actors.
2. The upcoming new economy or regime, is represented by new innovative players that enter the market. Promising innovations will be scaled.

At the early stages of transformation, established actors focus on optimization of their dominant systems and processes, referred to as the 'regime'. Due to new events the regime will experience destabilization. These events can be purposely initiated or might evolve independently, as is the case with climate change.

Emerging innovations, by nature, challenge the status quo or modus operandi of the dominant systems and processes and can therefore act as destabilizing factors in an organization or sector.

The established and upcoming regime meet in a state of chaos where established organizations will need new solutions that are provided by frontrunner companies. This will generate new ways of working which will gradually become institutionalized and grow into a stabilized new status quo.

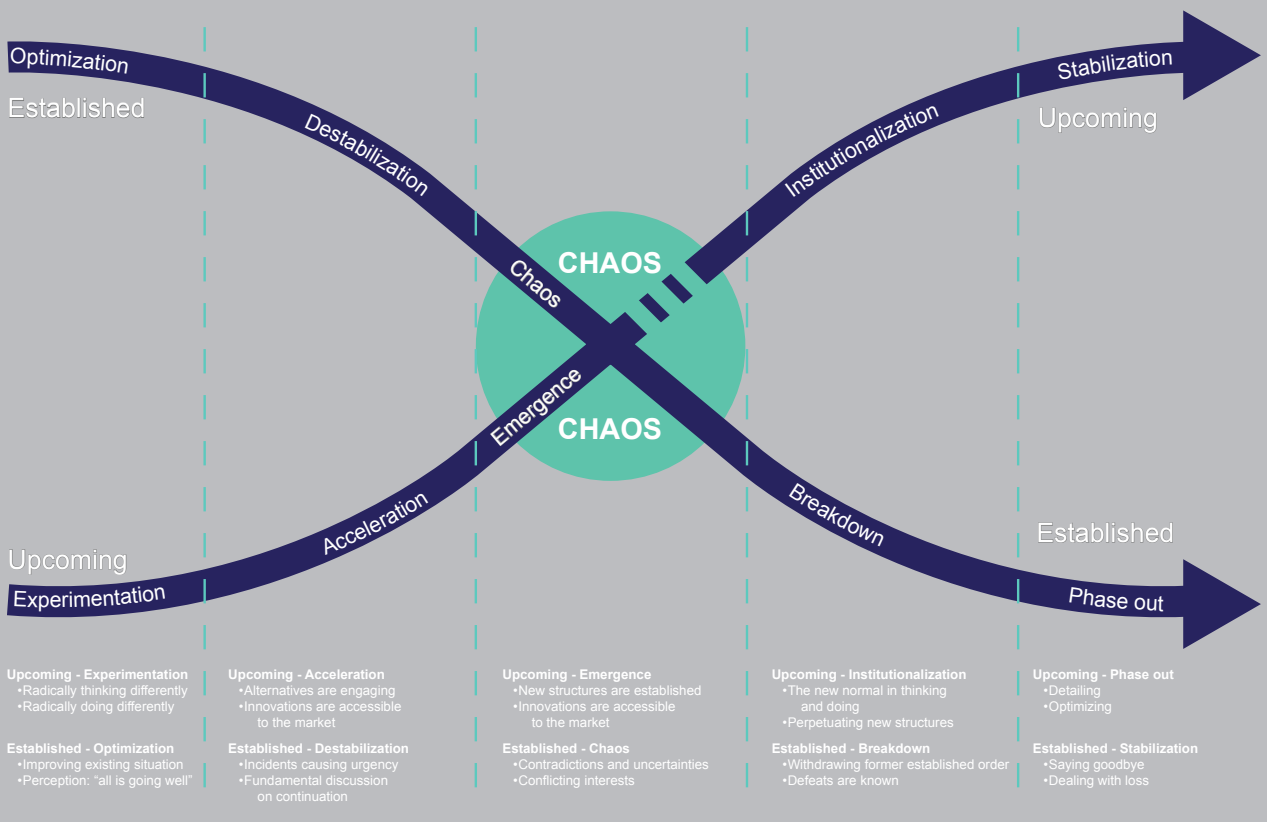


Organizations understandably resist experimental and potentially destabilizing emerging innovations as they can cause disruption. It is very complex to influence large-scale movement in a certain direction. Nevertheless there are several characteristics of each transition phase that can help to influence course or pace:

- Institutions such as governmental bodies have a role in destabilization, providing information about the state of affairs and stimulating a sense of urgency.
- It is clear that in all phases collaboration is key. This is especially relevant to the current digital transition, which in essence is about reconfiguration of business practices and information sharing.
- Transitions can be driven by big events such as societal or demographic changes and economic disruptions. These may be acute and sudden, as the COVID-19 pandemic has shown or can be very slow and almost invisible such as climate change.

It is, however, important to recognize that any technological transformation will come with a certain degree of disruption or destabilization. Tracing the dynamics of innovative transformations helps organizations to anticipate, prepare and strategically target their innovation efforts.

Figure 5: Schematic illustration of the X-curve as developed by Drift Institute for Transition



4 What has been holding us back?

4 What has been holding us back?

The potential benefits of increased digital integration within the construction value chain are clear. Not only would digital integration lead to increased efficiency in the sector, it would also lead to circular or more sustainable solutions. The question is why it has proven such a challenge to take full advantage of these benefits. In this section, we investigate the dynamics of digital transformation and why these are particularly challenging in the construction industry.

THE OPPORTUNITY IS THE CHALLENGE

Digitalization is claimed to be one of the most prominent transformative forces in society. Hinings et al. describe digital transformations as "the combined effects of digital innovations bringing about novel actors and actor constellations, structures, practices, values or beliefs that change, threaten, replace, or complement existing rules of the game in organizations, ecosystems, industries or fields".[40] By definition, digital transformations require regime changes and as such threaten to cause chaos and destabilization.

THE PROMISE OF PLATFORM TECHNOLOGIES

The digital landscape of the construction sector has been gradually evolving over the last decades. Digital building technologies have advanced rapidly and are increasingly integrated with general purpose platform technologies as outlined in **Box 1**. Drawing from the typology of digital building technologies, it becomes clear that the key to unlocking the benefits of digital integration in this sector lies in the adoption of platform-based technologies. Examples of platform-based technologies are Building Information Models, block chain and logistics platforms.

These technologies are generally geared towards transparency and traceability and have the potential to incorporate the contributions of stand-alone technologies. Platform-based technologies therefore, may yield direct and indirect benefits throughout all life cycle phases.

The wide-scale adoption of platform-based technologies poses a number of new challenges for the industry. The industry will need to share information, harmonize approaches, and collaborate across value chain boundaries and life cycle phases. These challenges are significantly distinct from earlier digitalization processes. The development and adoption of Computer Aided Design (CAD) technologies, for example, was targeted towards the improvement of a very specific standalone design task within a wider process. Placed on the X-curve (see figure 6), these developments can be characterized as optimization and sustainment of the existing regime, which does not affect existing silos in a fundamental way.

The value of harmonization

How Madaster unlocks the hidden value of materials

THE CHALLENGE

In the traditional linear economy building data transfer between different life cycle phases is limited. In the circular economy, information about resources and building performance needs to be stored and shared along the value chain. This requires an independent central registry of building material information to ensure secure data storage and usage as well as transfer from one owner to the next.

THE JOURNEY

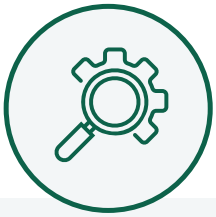
In a circular economy, materials that are 'temporarily stored' in buildings have a residual value that can be 'harvested' at end of life or when transformed to a new application. To recognize and optimize residual value, materials information should be available in all life cycle phases. It may take several decades or just a few years before this value gets unlocked. The Madaster platform is fully digital and collects and stores material information that is needed to determine materials' residual value over time, commonly referred to as material passports. The process of gathering data for material passports helps organizations to rethink efficiency, material use and construction, but has required substantial effort in terms of data harmonization and platform development. The value of material passports, however, is that traceability of materials helps recognize and optimize residual value at end of life or in transformations. This value can be included in organizations' balances. Madaster and its clients recognize it was and still is a learning process, where the approach has been founded on principles like starting simple and gradually increasing the complexity of things; from a traditional building with a passport on material level to a fully circular building with a 100% digital twin.

IN PRACTICE

Making material passports accessible is important to get actors on board. Madaster facilitates users by retrieving data from BIM models and connecting the outputs to impact data in a fully automated way. It is expected that in a few years, material passports will become mandatory for buildings. Meaningful harmonization is essential to scale these developments. Madaster therefore takes part in collaborations that aim at harmonization such as Platform CB'23 in which the Netherlands' construction value chain is represented, to develop a joint method for assessing the level of circularity of constructions.

Madaster is a brand name of the Madaster Foundation. It is designed as a public online library of materials in the built environment. The Madaster platform links the identities of materials to their locations, and registers these in a materials passport. The central, global data platform assures global alignment and consistency. It facilitates efficiency with respect to development, maintenance and security.

Material passports deliver value now and in the future



Explore the hidden value of our assets and learn to understand how to manage this value throughout the entire building life cycle

"The data is available. We only need to want to work with it"

Sander Beeks, Partnership Manager Madaster

THE MEANING AND IMPACT OF DIGITAL TRANSFORMATION

Because platform technologies require intensified collaboration along the value chain, as well as the allocation of resources beyond the scope of a single project, platform technologies challenge current industry practices. As outlined in Box 2, any challenge to familiar practices can be met with resistance to change. But there is evidence to suggest that digital transformations are particularly complex to navigate: A recent McKinsey study provides a quantitative perspective on this mechanism: organizations report positive outcomes on organizational transformations in only less than 30% of investigated cases. Digital transformations in particular are reported to be even more complex, with success rates of around 16% at best: "Transformations are hard, and digital ones are harder". Traditional sectors such as infrastructure, not commonly characterized as "digital-savvy", reported even lower success rates between 4% and 11%.[41]

A 2017 study by Bain & Company reports that only 5% of investigated companies report having been able to achieve or exceed the expectations for their digital transformation. Zooming in on the challenges that organization face in successfully navigating digital transformations, Wade.[42] distinguishes five fundamental factors that lead up to failure, all of which originate from a flawed or perhaps only partial understanding and subsequent conceptualization of the meaning and impact of digitalization in an organization.

Wade demonstrates that while it is tempting to direct a lot of focus to appealing and perhaps marketable elements (such as specific digital applications), more often, digital strategies result in merely digitizing existing business processes and therefore perpetuate silos and inefficient working methods. **Meaningful digital transformation requires an evaluation of an organization's most fundamental objectives, processes and dynamics and how digitalization could support those wider objectives.** This transition relates to Bengtsson et al.'s aspects of receptiveness to change: demonstrating ownership and leadership, defining clear objectives and setting coherent policies (see also 3.1).

CULTURAL TRANSFORMATION

Segmentation and project-based business processes do not incentivize organizations to explore the collective value of digitalization. Organizations are focused on their own structures and processes. With perceived limited margins, these organizations might remain reluctant to work together to form platforms or ecosystems and to develop cross collaborations between different life cycle stages.

The challenges companies have experienced while implementing platform-based technologies such as BIM, demonstrate that a change in the way we think, collaborate and conduct our business is required. The implementation of platform-based technologies uncovers precisely those systemic issues that have held back the sector's productivity, transparency and sustainability performance for decades (see also Chapter 2), in particular the attitudinal and institutional barriers that inhibit change in the construction industry.

If the success of implementation of digital technologies or strategies depends mostly on the characteristics of an organizational culture, any digital transformation will have to be preceded by a cultural transformation, where attitudinal barriers such as risk-averse behavior and focus on short term (project) objectives are minimized. Conversely, organizations can actively stimulate contributing cultural factors such as demonstrating ownership and leadership, coherent policies, but also effective professional relations and networks in a supportive cultural context. Digitalization may not be the key to tackling those barriers but may well function as an impulse to address our collective challenge in a truly fundamental way.

WITH LIMITED INVESTMENT IN R&D, INNOVATIONS ARE LESS LIKELY TO SCALE FAST

Generally speaking, the construction sector invests relatively little resources in R&D. With low productivity and limited margins there are few organizations that make significant financial investments in R&D (see 2.1). The overall spending on R&D within the construction sector is accounts for less than 1% of the revenues, while other sectors spend about 4%.[43] The sector is slow in embracing innovations. This problem could be exacerbated by failure to meet investors' and shareholders' external reporting requirements, which increases the cost of, or limits the access to capital.

Innovation often takes place in the context of an individual project, which makes replication challenging and harms the business case of innovative solutions in terms of scalability and profitability. Furthermore, financial investment can only have a meaningful impact in a receptive context (see 3.1). This means that organizations will have to invest resources, support and leadership effort to bring out the necessary cultural and behavioral change.

BOX: 3
WHAT CAN WE LEARN FROM OTHER SECTORS?

The construction sector is not the only industry that faces the challenges of digital transformation. By investigating possible commonalities between the construction sector and other industries' digital journeys, a number of key lessons can be identified.

HARMONIZATION OF DATA STANDARDS

Meaningful information exchange and use depend on accessibility of data, interoperable data standards, and a shared understanding of the quality, reliability and accuracy of information.
One example of a large scale international effort aimed at data standard harmonization is the European Union's INSPIRE Directive in the early 2000's, aimed at improving accessibility, usability and interoperability of spatial data sets by establishing an infrastructure for spatial and environmental information.

Digital Geographical Information Systems (GIS) have dramatically impacted the way we analyze, use and apply spatial and environmental information today. GIS applications range from design, engineering and construction applications as well as a wide range of consumer oriented and public services. Initially developed in the early 1960s for the purposes of land use management,[44] technological advancements in computing power have led to the wider application of GIS throughout the 1980s and 1990s, both commercially and in the public sector.

The availability of an abundance of spatial and environmental data in combination with increased awareness of the relevance of this data for fostering sustainable development, has led to the initiation of the INSPIRE Directive. During the preparation of the Directive, the following barriers for widespread use of spatial data were identified:

- Missing or incomplete data
- Incomplete or lacking metadata
- Lack of interoperability of datasets
- Lack of interoperability of spatial data repositories
- Institutional or regulatory barriers that inhibit sharing and multiple uses of spatial data.[45]

The approach to overcome these barriers has been the development of a spatial data infrastructure, which includes harmonized data specifications, implementation guidelines, standards for metadata, services, regulations as well as an information portal.[46] In a 2016 cost-benefit analysis, it was estimated that the INSPIRE initiative, in addition to having improved quality and availability of spatial and environmental data, has resulted in benefits such as (but not limited to):

- Efficiency gains for governmental agencies as well as data providers
- The development of value added services in the private sector
- Improved governmental decision making and service delivery
- Societal benefits such as avoided damage and a positive contribution to scientific research.[47]

The INSPIRE initiative demonstrates that harmonization and standardization through institutional regulation can lead to real societal benefit.

THE JOURNEY: PROLIFERATION, THEN CONSOLIDATION

In the past two decades, the agro-food sector was subject to a proliferation of certification schemes that aimed at stimulating more sustainable (environmental, economic and social) practices in production and processing of food and feed. For specific production methods, regions, value chains, topics and products, new certification schemes have evolved. Digitalization enabled better information collection, management and analysis and helped to increase transparency. However, over time and for each certification scheme, new digital solutions were developed. This led to a significant administrative burden, unclear investment opportunities, inefficiency and perverse incentives for producers, which in the end did not contribute to consumer value. As a result, a number of certification schemes merged, for example UTZ Certified and Rainforest Alliance with the aim to benefit both producers (simplification) and their members (more efficient value chains).[48] Digitalization followed suit: information systems were merged and best practices were shared and scaled.

Another example from the same sector is the work of the Sustainable Agriculture Initiative Platform in which global food companies are united.[49] One of the key achievements of the platform is to develop the Farm Sustainability Assessment (FSA), a self-assessment tool for suppliers to evaluate sustainable production practices.[50] The development of one single FSA should replace the individual supplier codes of the big companies. Previously, producers had to comply with each individual code to sell their products, and with rotating crops, this could result in having to apply new practices each year. Besides an abundance of administrative work, this also did not provide a solid base for producers to invest in sustainable practices. The FSA resulted in a better understanding of sustainable practices at supplier level, channeling investment toward long-term improvements on production sites while alleviating the administrative burden for participating food companies.

The FSA offered a common approach to sustainability assessment in the industry and as such has supported scaling sustainable practices. In the last few years the SAI platform has developed an online environment for the FSA to make the process more efficient and to connect and benchmark it to other collective sustainability systems in the agro-food sector.[51]

EMERGING PLATFORM SOLUTIONS

We cannot investigate digitalization without looking at overwhelmingly successful big tech companies such as Google, Amazon, Facebook and Apple. These digital frontrunners impact our everyday lives through digital (platform) solutions and a wide variety of consumer applications. It is tempting to aspire to emulate these frontrunners. However, there are fundamental differences between these technology giants and the construction industry.

Though the construction industry can benefit from a more data-driven approach to design, engineering and construction, the data needed to support those primary processes are fundamentally different from the information these big technology companies collect and utilize. The primary resources for these tech giants are predominantly user data, combined with cloud (computing) services or a form of e-commerce services. The information most relevant to the construction industry, asset information, will have to be actively collected with a clearly defined objective in mind, as opposed to tracking information that is the by-product of platform use behavior.

Research by the Joint Research Centre of the European Commission (JRC) in 2019 demonstrated that in Europe, platform technologies developed by SMEs contribute significantly to disruptive digital transitions and therefore are key drivers for digitalization.[52]

These platforms are especially significant because they link information sources and accelerate processes, disclose and unlock information, improve access to finance, link the availability of (circular) resources to buyers and mediate access to jobs. The report identified that for these SME platforms, scaling-up proves to be the biggest challenge. This relates to a fragmented market and whether the SMEs were located in a supportive innovation ecosystem.

Another example of how platforms are developed and are part of the future of digitalization is drawn from the more technology-driven agricultural sector. In the agriculture sector in developed economies, the once solitary tractor has transformed into a digital platform for crop management. The vehicle has been linked to satellite data; the farmer is provided with real time feedback about its performance which in turn is linked to online platforms that can be managed with a PC application. Information from the seed company and clients, from weather forecasts, the manufacturer of the tractor and the farmer is combined in one cross sectoral platform that aims to optimize resource use and crop yield. This example shows that a once solitary piece of machinery can become a platform on its own.

DIGITALLY ENABLED OPTIMIZATION IN MANUFACTURING

Industry 4.0, which is also recognized as the fourth industrial revolution, is changing manufacturing processes rapidly. In manufacturing, the 'smart factory' is emerging.[53] The smart factory connects physical production to digital information. An example of this is Fraunhofer, who are developing the factory of the future based on the 'cyber-physical equivalence' concept.[54] Their physical production line is in continuous contact with a cyber environment, allowing for continuous adaptation and optimization, which dramatically increases flexibility and efficiency of the process. Through applying an IoT solution, Harley Davidson managed to reduce manufacturing time from 3 days to 6 hours and Ford motors reduced maintenance costs by using drones to perform risky and time-consuming inspections in a plant in London.[55, 56] This approach leads to efficiency gains, ultra-short production chains and less down-time.

The tendency to create efficient, automated mass production grows in parallel with local, ultra-flexible small-scale production enabled by 3D printing technologies. These technologies allow to produce custom made and instantly needed products based on virtual designs, through fast prototyping, thereby accelerating the design process.[57]

These technologies have also changed the interaction between customers and manufacturers. New direct-to-customer business models have been introduced that harness the power of the web and connect consumers to manufacturers through mobile devices and online applications. Digital technologies, such as the IoT, remote monitoring, analysis of big data and artificial intelligence are expected to change the nature of manufacturing companies: from a product provider to a solutions provider.[58,59] By creating a virtual-physical connection, the manufacturing sector has been able to involve consumer demands more predominantly in their production processes.

The manufacturing sector has experienced the benefits that digitalization has to offer. It has enabled massive efficiency gains and has altered the entire production process. The construction sector is considered as more complex. However, the construction of a building as a manufacturing process may deliver valuable new insights about how digitalization can enable a sustainable future-proof construction sector, as proven by Bryden Wood.

Investing in digital innovation

How Stora Enso has capitalized on cross-value chain collaboration by harnessing the potential of digitalization.

THE VALUE CASE

The building and construction industry has the tendency to operate in silos, which often leads to duplication of work and the lack of effective networks spanning the length of the value chain. Digital solutions have an important role to play in enabling this cross value-chain efficiency, which will be important in the transition to a low-carbon, circular economy, for sustainable use and reuse of materials.

THE JOURNEY

Stora Enso has committed significant time and resources to better understanding the technology-driven leaps that can help address the current fragmentation that exists in the value chain and help enhance the efficiency of the sector. By investing in a Digitalization fund at a company level, they have been able to pursue a broad scope of collaborations to develop innovative ways of doing things. The buy-in of senior leadership through this funding has been critical in driving forward the exploration of digitalization to improve inefficiencies. Engaging with start-ups through co-creation and open collaborative environments has allowed Stora Enso to advance its building solutions, BIM platforms and material concepts, enabling further innovations upstream and downstream, from forest management, through to the manufacturing, logistics, construction and range of material utilization.

The track and trace of materials is a crucial element to advancing the circularity and allowing the quality for reuse at the end-of-life stage. Through establishing 'Phygital' (physical meets digital) approach, and by creating digital solutions to accompany their materials, the entire process of material's lifespan can be accessed to understand the origins, treatment, condition of specific assets, elements and materials. This provides Stora Enso with competitive advantages. The use of 'phygital' and 'digital' twin technologies enable asset monitoring in real time, where integrated sensors report back the conditions, preventing issues before they arise. This promotes sustainability goals by avoiding inefficiencies, ensuring proper utilization and limiting energy and waste.

IN PRACTICE

Although leveraging digitalization is a competitive advantage in the slow-moving building and construction industry, eventually it surely will be recognized as the next critical component to reaching circularity and valued sustainability targets. Especially financial incentives will be a key driver on digitalization to enable efficiency and circularity across the value chain. Further, government legislation addressing embodied carbon and introducing carbon reduction targets are needed to drive forward this transitional shift across the entire construction sector. But also, this includes setting increasingly ambitious high and new standards for the minimal acceptable use of sustainable materials and solutions to scale the circularity efforts that the front-runners already are pushing.

Stora Enso develops and produces sustainable solutions based on wood and biomass for a range of industries and applications worldwide. Their products and technologies are based on renewable materials, and their whole approach is underpinned by the sustainable management of resources.

Digitalization allows for a more efficient network across the value chain, enabling circularity through end-of-life, from sustainable forest management to material harvesting and reuse.

Digital collaborative platforms that engage stakeholders and start-ups facilitates the co-creation and scaling of innovative solutions

"There is no doubt about it, digitalization brings added value and competitive advantage"

David Blomquist
Director of Digital Business, Stora Enso

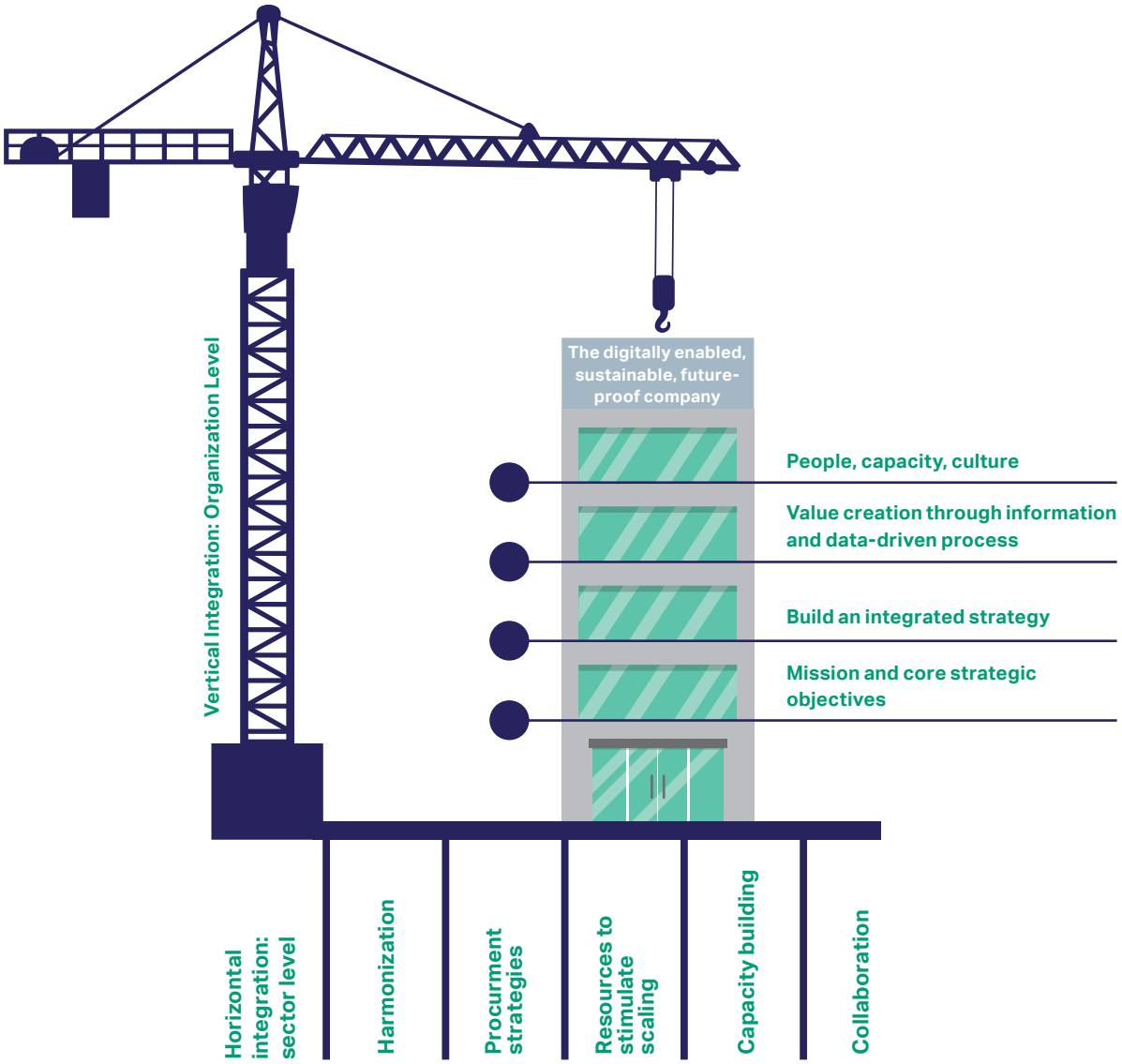
5 Recommendations for a digitally enabled future-proof, resilient and sustainable built environment

5.1 RECOMMENDATIONS FOR A DIGITALLY ENABLED FUTURE PROOF, RESILIENT AND SUSTAINABLE BUILT ENVIRONMENT

As has been demonstrated throughout this report, digital technologies can support sustainable practices in a number of fundamental ways. What has also become apparent, is that the success of digital transformation is not determined by technological advancement alone, but highly depends on the institutional, organizational and cultural context. The key to unlocking the potential of digital technologies and to supporting sustainable practices lies in collaboration. It requires **vertical** as well as **horizontal** integration of digital processes within and among organizations as depicted in Figure 7.

Individual organizations as well as institutional actors in the construction industry have the power to actively stimulate progress toward digitally supported sustainable practices. The following sections outline the key recommendations derived from the desktop research and case studies that have been conducted as part of this report.

Figure 7: Recommendations to stimulate horizontal and vertical integration



5.2 RECOMMENDATIONS FOR ORGANIZATIONAL TRANSFORMATION

Reflect on the organization's mission and core strategic objectives

Transitioning toward sustainable operations requires a change in an organization's core processes. Change causes disruption and, if not guided in a meaningful way, is more likely to lead to resistance which could undermine the effort. One of the essential and recurring recommendations interviewees have shared, is that meaningful organizational change strategies are founded on a clear understanding of why change is needed and why collective effort is a key prerequisite to success.

The starting point should therefore be a methodical and critical reflection on an organization's or business unit's mission and objectives. On C-suite level, leadership should be able to determine the extent to which these core values are reflected in the wider business practices, results and overall impact in light of sustainability challenges. The business continuity framework presented in this report is an effective starting point to analyze, structure and prioritize the elements of required organizational change. In addition to traditional considerations such as technological and consumer trends, digital trends and developments should take a central role in determining the mission and objectives. It will require a long-term scope to understand how the organization can continue its business on the long run, especially in relation to other trends such as climate change and resource scarcity which require a long-term perspective.

The Digital Transformation Approach has been developed to design a comprehensive and action-oriented digital transformation roadmap on that addresses strategic, tactical and operational level. This approach is explained in more detail in the case study by PIT Digital Transformations.

How PIT helped BAM Energy & Water to create focus in their digital strategy

THE CHALLENGE

Many ambitious organizations focus on getting started immediately with digitalization, without taking the necessary time to consider how their digital strategy relates to their day-to-day operations. This lack of planning and direction leads to unfocused efforts, thereby increasing the risk of fragmentation, financial losses due to failure and eventually inaction. According to PIT, the key to successful investment in digital transformation lies in the first step: developing a targeted strategy.

THE APPROACH

To guide organizations through this crucial phase, PIT has developed a structured and action-oriented approach to the targeting phase, resulting in direction, focus and a framework to base the subsequent planning phase on. This approach has been applied to outline a specific digital transformation for BAM Energy & Water Infrastructure.

IN PRACTICE

Network operators in the Netherlands usually organize construction of underground utilities in framework contracts that regionally cluster a high volume of work orders over a period of several years. Execution of these projects requires certified technical personnel, of which there is a shortage on the Dutch labor market. BAM Energy & Water based its digital strategy on an internal and context analyses.

Strategic internal analysis: Its technical expertise did not distinguish BAM Energy & Water from other actors. Competitive advantage is based on process quality management requirements: technical administration, information management and communication. Uniform processes, information management, reduced administrative are key determining factors for success.

Strategic context analysis: The energy transition comes with a challenge to find sufficient qualified technical personnel. In addition, client satisfaction is increasingly influenced by the quality of digitally enabled service delivery e.g. related to user experience, ease of use, client self-service functionalities.

The digital strategy focuses on a few components

- Own the demand: Focus on optimization of capacity management so BAM Energy & Water can comply with the demand for high volumes of work orders. Organize assignments like a marketplace, where personnel (staff and contractual) can access and accept individual work orders.
- Offer favorable working conditions through an exceptionally organized digitally enabled working process, which minimizes the burden of technical administration. In addition, contract personnel are now enabled to select specific work orders based on travel distance and working hours.
- Optimization of user experience by offering end-consumers the flexibility to independently schedule work orders, deliver site information and feedback through a rating system that is used to improve service delivery and performance.
- Optimization of client experience (grid operators) by delivering a uniform, digitally supported working process that is manageable, verifiable and enables continuous improvement of services while minimizing risk of failure while simultaneously optimizing speed of service delivery.

PIT Digital Transformations is a Netherlands-based consulting firm focusing on the development and execution of digital transformation strategies for clients.

Setting the right strategic direction requires insight and vision

Direction + plan + targeted action = digital success

"Without successful digital transformation, the future-proof organization is an unattainable ambition."

Ruurd Portman,
Founder of PIT Digital Transformations

BUILD AN INTEGRATED STRATEGY

Understanding and substantiating the necessity for change and a clear definition of the organization's collective objectives forms the foundation for a framework which outlines what the specific needs and consequences are for individual business areas. If the key driver for change is to improve energy efficiency in operations, the strategy and required resources would be fundamentally different from improving sustainable design capabilities. The result of this phase is a high-level gap analysis as well as an outline of what is needed to bridge the identified gaps.

Isolated sustainability or digitalization strategies perpetuate siloed thinking and practices. **The findings presented in this paper underscore the need for integrated approaches to strategic transformation: the strategy needs to encompass all areas of the business and not focus on individual pockets.** An integrated strategy describes how strategic objectives are operationalized and encompass all activities, tools, resources, checks and balances needed to drive the desired change. Digitalization is one of the aspects to consider in those cases where it realistically contributes to overarching strategic objectives, such as resource efficiency, operational optimization, sustainable practices or improved transparency. From the integrated strategy, a set of coherent and targeted policies can be derived that define direction and that provide a shared guidance framework. Best practices include:

- A combination of top down and bottom up approaches. Strong "digital-savvy" leadership at C-suite is an important determining factor for digital success, but needs to be complemented with tangible results on an operational level;[60]
- The strategy should have full support of all layers of management. Besides C-suite leadership, middle management that oversees translating the strategy to the work floor should be on board. Interviews confirmed that, for instance, a strong focus on operational level, did not lead to successful implementation of digital solutions because the connection and support of other business units was absent. From interviews, we also learned that when C-suite ambitions were not translated to the core processes in organizations, at operational level there was limited uptake;
- The strategy should stimulate cross-collaboration between the different compartments of the organization;
- The strategy requires a critical evaluation of the long-term efficacy of existing business processes, information and knowledge management practices in relation to strategic objectives.

VALUE CREATION THROUGH INFORMATION AND DATA-DRIVEN PROCESSES

Meaningful organizational transformation is not achieved through merely digitizing existing business processes, or defining sustainability as just a 'nice to have' addition to a traditional project. **The transition towards a digitally enabled sustainable and circular built environment requires a fundamentally different approach to design, engineering, production and construction processes.**

A few examples were given by the companies we have interviewed. Bryden Wood stressed the need to stop and (re)think before you start building. Madaster recognized that the process of gathering data for material passports helps organizations to rethink efficiency, material use and construction. Similarly, Skanska highlighted that digitalization requires a cultural shift within companies.

Rethinking existing practices allows to bring sustainability and circularity at the core of the business processes, identifying inefficiencies and promoting optimization.

Digitalization and data-driven business processes require new and often differing approaches from business as usual. In addition to recruiting staff with the right skill sets, organizations will have to invest in creating awareness and capacity building to the existing workforce. But given the influence of attitudinal barriers on organizational change, fostering a collective innovation-oriented culture should be incorporated in companies' strategy and policies.

Best practices include supporting a culture that:

- is value-focused, rather than cost focused (e.g. Skanska case study)
- conceptualizes sustainability as a built-up factor for consideration in projects (e.g. Autodesk case study);
- is receptive and adaptive to change by actively recruiting the skills and competences required to support strategic objectives and effect change; [41, 60]

5.3. RECOMMENDATIONS AT SECTOR LEVEL

The success of sectoral transformation depends on the efforts of individual organizations. As has been noted in the Skanska and Stora Enso case studies, governmental and institutional actors, such as contractor representative organizations can help stimulate both sustainable practices and digitalization in a number of meaningful ways.

HARMONIZATION AND STANDARDIZATION

As demonstrated in Box3, harmonization of data standards can be an important step towards acceleration of digitalization. Institutional and governmental stakeholders have the ability to initiate harmonization of data standards, thereby stimulating improved data interoperability, information exchange and leveling the playing field through improved data accessibility. Harmonization can be a powerful driver for improved efficiency, innovation and collaboration in the construction value chain. Other examples relevant to the construction sector include:

- the buildingSMART International community, aimed at developing open data standards for the built asset industry[61]
- the Gemini Principles, which outline shared guidelines, roadmap and information management framework for the development of a national Digital Twin in the UK.[13]
- the Madaster initiative, which aims at standardization and disclosure of building material information.

However the development of such harmonized data frameworks is complex and requires substantial investment, making it hard for individual private sector organizations to build a meaningful business case. Governmental, institutional or NGO stakeholders are therefore important drivers for concerted action of private and public actors.

Figure 8: Recommendations for horizontal sectoral integration

Harmonization

Create harmonization to facilitate information exchange, increase mutual understanding and stimulate scaling digitalization in the constructions sector.

Facilitate collaboration

Encourage platform collaboration to co-create innovations, exchange relevant information flows, support collaboration and harmonization.

Support capacity building

Support capacity building by stimulating education and awareness. Develop knowledge and share open source data about the built environment.

Provide resources to scale

Provide resources to experiment with, to test and scale digitalization. Use regulations and compliance systems to create a level playing field for scaling promising digital developments.

Change procurement to foster innovation

Procurement strategies traditionally are risk-based and award low prices and tight planning. Procurement needs to foster innovation and stimulate cross sectoral collaborations.

STIMULATE AND FACILITATE COLLABORATION

Especially as climate change, urbanization and consumer demands transcend the dimensions of individual projects, collaboration is needed. As has been demonstrated in Box 3, platforms have the potential to stimulate and enhance collaboration across the value chain and among actors. Improved accessibility of environmental and asset data improves the quality of design, engineering and construction solutions and may provide opportunities for innovation. For a platform to become a valuable collaboration tool there are some considerations to take into account:

- Platforms should facilitate cross-sectoral collaboration and exchange of information;
- Platforms should encourage harmonization between the various participants in a platform;
- Platforms should provide a pre-competitive arena in which organizations have the freedom and security to collaborate, share knowledge and innovate.

Collaboration is especially relevant as the complexity of the challenges at hand, such as climate change, resource scarcity and urbanization, requires a harmonized approach that crosses sectoral and regional boundaries. Concerted considered effort from public, private and institutional actors are needed to foster alignment and to build and sustain these collaboration platforms.

SUPPORT CAPACITY BUILDING

As individual organizations work to improve digital capacity, governmental and institutional actors can play an important role in supporting these efforts through knowledge development and dissemination. Examples include:

- Raising awareness by actively sharing best practices that demonstrate the value of digitalization for sustainability;
- Development and facilitation of training or adaptation of existing curricular;
- Incentivizing change in business processes.

INVEST IN SCALING INNOVATION

To become cost-effective alternatives to business as usual, circular and sustainable innovations need support and resources to scale. Governmental and institutional actors have the ability to help, to drive and scale sustainable solutions through facilitating networking or investment platforms such as startup ecosystem platforms or revolving funds.

CHANGE PROCUREMENT PRACTICES TO FOSTER INNOVATION

As has been outlined in Chapter 2, current procurement practices have been identified by Vennstrom et al. as contributing to industrial and institutional barriers to and adversely affecting change in the construction industry. To support the transition from competition-driven and profit-protection attitudes toward a value-driven, innovative and collaborative construction sector, procurement processes and regulation should reward or incentivize:

- Sustainable and circular practices, including quantification or monitoring schemes of sustainability performance;
- Information exchange and collaboration across multiple life cycles;
- Collaborative process and product innovation.

Actors in this field may form coalitions to reform procurement practices and regulations to stimulate innovation and sustainable outcomes in the built environment.

6 Conclusion

6 Conclusion

SUSTAINABLE PRACTICES ENSURE BUSINESS CONTINUITY

Sustainable practices are no longer just 'nice to have' for the construction sector. Making a meaningful contribution to a more sustainable, safe and healthy built environment is no longer the ambition of single clients, but is increasingly required by society. In parallel, climate change, resource scarcity and increasing complexity of the built environment create new pressure for actors in the sector. Sustainable practices are therefore key prerequisites to ensure business continuity and license to operate.

DIGITALIZATION HAS THE POTENTIAL TO SUPPORT SUSTAINABLE PRACTICES AND BUSINESS CONTINUITY

Digital building technologies already support the various stages of the asset life cycle and **operations** of actors in the value chain from exploration, to design and engineering, construction, maintenance and dismantling. **Autodesk's** work shows that the use of digital information technologies, sophisticated analytics such as parametric design and modeling techniques help deal with the increasing complexity of operations and result in more sustainable design. As has been demonstrated in the **Bryden Wood, Madaster, Skanska** and **Stora Enso** cases, digital and information-driven approaches to design and value chain integration accelerate sustainability by reducing the environmental impact of designs, enhancing efficiency, optimizing resource use and supporting collaboration in the value chain.

Digital solutions support organizations in methodically gathering, analyzing, verifying, reporting and improving sustainability performance information on organization- and project level. The **Arcadis** case study shows that digital transformation in sustainability reporting leads to value creation and improved business performance and allows organizations to make integrated and proactive data-driven decisions that reduce environmental impact. In addition, these digital solutions help meet regulatory **compliance** requirements, support internal and external reporting and by doing so strengthening **public image.** Moreover, organizations' environmental, social and governance performance and the quality of their public disclosure increasingly affects investors' and shareholders' **investment decisions.**

A SECTOR IN TRANSFORMATION

Sustainable practices require actors in the construction sector to adapt their approach to construction and the built environment. Siloed working, primary resource use, lagging productivity and increased complexity caused by new sustainability requirements to design, engineering and construction all put the long-term health of the sector at risk. To ensure business continuity, the sector will need to redefine business as usual and transform into an innovative, collaborative, efficient and sustainable industry. As has been demonstrated throughout this report and in almost every case study, digital transformations can be particularly challenging for organizations in the construction sector. Interviewees agree that technology is hardly ever the most challenging part of digitalization. **Skanska** outlines how digital transformation requires a cultural shift from the current focus on cost toward a focus on value of sustainability as well as digitalization. **Autodesk** and **Arcadis** underscore that the road to sustainable practices through digital transformation is a matter of change management: to create real value and impact, sustainability needs to be conceptualized as a core driver for value creation.

PREREQUISITES FOR CHANGE

Digital platform technologies may help unlock the benefits of digital integration in the construction sector. The implementation of platform-based technologies however uncovers precisely those systemic issues that have held back the sector's productivity, transparency and sustainability performance for decades (see Chapter 2).

Working together to accelerate the digital shift

Skanska regards collaboration as a crucial part of the industry's digitalization journey

THE CHALLENGE

A major barrier to overcome is fragmentation, both within companies, and across the industry. There is a need for a more integrated system to reduce inefficiencies at company level, and to establish more cross-sectoral collaboration. The adoption of digitalized operations is hampered by the industry's focus on cost rather than value. More emphasis needs to be placed on the long-term value of investments.

THE JOURNEY

Skanska Sweden divides its focus on digitalization between two key areas. Firstly, through digitalizing their projects by exploring and implementing data-driven ways to increase efficiencies across the suppliers and systems that they use. Secondly, through addressing the use phase of their products, by advancing different types of end-products- such as digital maintenance software. The latter focus has stemmed from an increase in customer demand for digitalized capabilities in the design and use phase, from Digital Twins software to technology that monitors the energy consumption.

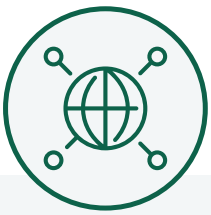
Throughout the development of their digitalization efforts, Skanska Sweden has recognized the crucial role that collaboration within the industry plays. By sharing principles and experiences with partners and competitors, the entire industry benefits through accelerating the transition toward a digital field. Cultural shift would be required within a company, to ensure that resources are invested into training, education and awareness of the digital solutions that built in to the every day practice of organizations.

IN PRACTICE

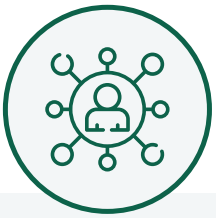
The Embodied Carbon in Construction Calculator (EC3) was developed by Skanska, in partnership with Autodesk, to help customers choose carbon-smart materials with lower embodied carbon. The free, open-source tool allows building professionals to quickly compare different materials in minutes - a task that previously took a team of experts days. The EC3's debut on a major project, the Microsoft Campus Redesign (a new 2.5 million ft2 workspace) generated reductions of the embodied carbon by ~30%.

Skanska AB is a Sweden-based multinational construction and project development company. Their operations are divided into 12 business units in three operating segments: Construction (both building and civil); Residential and commercial property development and Infrastructure Development.

SKANSKA



Digitalization requires a cultural shift within companies, toward a focus on value rather than cost.



Substantive change will require collaboration with competitors across the industry. A single company cannot push forward the transformation alone.

"Digitalization will demand new skills and different ways of doing businesses, and in this way, it provides an incredible opportunity for companies to demonstrate leadership."
Per Boström, CIO at Skanska

Glossary

DIGITIZATION

Digitization is the process of changing data from an analog to a digital form.[62] In relation to the built environment, it refers to the flow of digitized information within and between a building's life cycle phases.

DIGITALIZATION

Digitalization is the integration of digital technologies into everyday life. Digitalization means that interactions, communications, business functions and business models are transformed into (more) digital forms, thereby changing the process.[63]

Digitalization – the development and deployment of digital technologies and processes - has the potential to enable increased transparency, efficiency and new functionalities along the entire value chain, i.e. from the design phase to the very end of an asset's life, the demolition phase. It supports collaborative work and efficiency gains through the smart use of data and analytics.

THE BUILT ENVIRONMENT

The built environment is where we live. It contains our homes, offices, the infrastructure around us, our entertainment and leisure spaces and green areas. It helps people thrive, it is a primary employer and it represents a significant share of national wealth.[64]

SUSTAINABILITY

Sustainability is defined as meeting the needs of the present population without compromising the ability of future generations to meet their need.[65] This will result in a world where the depletion of natural resources is avoided in order to maintain an ecological balance that is compatible with the boundaries of our planet. Sustainability also focuses on the social environment (health and safety, ethics, diversity and inclusion) required with a view to the future for mankind and nature.

CIRCULAR ECONOMY

In a circular economy, resource use is decoupled from economic growth, meaning that economic development no longer requires our current unsustainable resource consumption patterns.[66] Resources are used more efficiently, and the economy becomes less dependent on non-renewable resources. The circular economy is based on an emerging economic model that covers both techniques and business models to keep materials and resources in use as long as possible, and ideally forever, in a closed cycle of extended use, reuse and recycling.[67]

Critical components of the circular economy are industrial symbiosis, renewable materials, shared economy, 'product as a service', a close relation between producer and consumer, proximity economics, reuse, recycling and upcycling, urban mining, detoxification of material cycles and sustainable consumption and production.[67]

Opposite to the circular economy are single use, programmed obsolescence, downcycling, legacy substances or loss of value.[37]

PLATFORM TECHNOLOGIES

Platform technologies are digital technologies that connect several users, information flows and technologies through uniform databases and interface. Applications of platform technologies can be valuable in all life-cycle phases of a building.[29]

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