Sustainability, Productivity, and Cost Effectiveness of Construction

Civil Engineering
Construction & Graphics

Lecture # 26

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Sustainability, Productivity, and Cost Effectiveness of Construction Shaping the Future of Construction

- The world is changing faster than ever before. Consider just one of the global megatrends shaking up the construction industry: the population of the world's urban areas is increasing by 2,00,000 people per day, all of whom need **affordable housing as well as social, transportation and utility infrastructure.**
- In the face of such challenges, the industry is almost under a **moral obligation to transform.**
- Its transformation will have **transformative effects** elsewhere:
  - on the wider society, by **reducing construction costs**;
  - on the environment, by improving the use of scarce materials or by **making buildings more eco-efficient** over time; and
  - on the economy, by narrowing the global infrastructure gap and **boosting economic development** in general.

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- While most other industries have undergone tremendous changes over the last few decades, and have reaped the benefits of process and product innovations, the Engineering & Construction sector has been hesitant about fully embracing the latest technological opportunities, and its **labor productivity has stagnated** accordingly.

- This **unimpressive track record** can be attributed to various internal and external challenges:
  - **the persistent fragmentation of the industry,**
  - **inadequate collaboration with suppliers and contractors,**
  - **the difficulties in recruiting a talented workforce,**
  - **insufficient knowledge transfer from project to project, etc.**

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- The industry has vast potential, however, for improving productivity and efficiency, thanks to digitalization, innovative technologies and new construction techniques.
- Consider the **rapid emergence of augmented reality, drones, 3D scanning and printing, Building Information Modelling (BIM), autonomous equipment and advanced building materials** – all of them have now reached market maturity.
- By adopting and exploiting these innovations, companies will boost productivity, streamline their project management and procedures, and enhance quality and safety.
- To capture all this potential will require a committed and concerted effort by the industry across many aspects, from technology, operations and strategy to personnel and regulation.

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- The digital revolution of the last half century has made the world a much smaller place – opening markets, creating new products and goods, and facilitating rapid industrialization in emerging economies.
- The pace of innovation, with improved communication and increased productivity, has been remarkable in many sectors, including health sciences, education and consumer goods.
- The Engineering and Construction (E&C) sector has been slower to adopt and adapt to new technologies than other global sectors.
- While innovation has occurred to some extent on the enterprise or company level, overall productivity in the sector has remained nearly flat for the last 50 years.
- As an industry based on competitive procurement models, E&C has historically taken a conservative approach to product design and delivery, leading to silos in project management and a somewhat fragmented industry.

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- This slow pace of innovation matters, because of the great scope and scale of E&C. The industry accounts for about 6% of global GDP and is growing. In parts of the developing world, such as India, it can account for more than 8% of GDP. E&C is the largest consumer of raw materials and other resources, using about 50% of global steel production and more than 3 billion tonnes of raw materials. Any improvement in productivity and successful adoption of modern innovative processes will have a major impact. For example, a 1% rise in productivity worldwide could save $100 billion a year.
- Multiple global megatrends are shaping the future of construction. Consider just two developments: first, 30% of global greenhouse gas emissions are attributable to buildings (at the same time, the UK government has set a target for 2025 of 50% reduction in today's level of greenhouse gas emissions in the country's built environment).
- In the United States over the last 40 years, for example, labor productivity in the construction industry has actually fallen.

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- The **eight topical areas** are:
    1. Technology, Materials and Tools
    2. Processes and operations
    3. Strategy and business model innovation
    4. People, organization and culture
    5. Industry Collaboration
    6. Joint industry marketing
    7. Regulation and policies
    8. Public procurement

Figure 1: Industry Transformation Framework

Sustainability, Productivity, and Cost Effectiveness of Construction Shaping the Future of Construction

1. Technology, Materials and Tools

- Building Information Modelling (BIM) plays a central role here, as it is the key enabler of and facilitator for many other technologies: the building of a bridge, for example, can be greatly facilitated by **combining robotics and 3D printing via a parametrically designed 3D model.**

- Another extremely powerful lever for innovation is that of construction materials; the associated solutions are numerous and wide-ranging – from incremental innovation of traditional materials and existing characteristics to radically innovative materials with entirely new capabilities.

- Although many innovative solutions are already being applied on a small scale or in a few countries, **the industry still needs a large-scale application or better adaptation of current technological developments.**

- To unlock the potential inherent in new technologies, materials and tools, the industry also needs to adopt the relevant respective processes. For instance, the **benefits of BIM** are reinforced if companies exploit the new ancillary opportunities it offers – notably, a **new way of collaborating and sharing information between stakeholders.**

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2. Processes and Operations

- Large productivity improvements can be achieved by optimizing existing processes: the broader use of “lean” principles and methods, for instance, **could reduce completion times by 30% and cut costs by 15%.**

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3. Strategy and Business Model Innovation

- Another core lever is early project planning. To improve such planning, companies should promptly draw on the knowledge of all stakeholders, and should **explore new contracting models**.

- **A minimal increase in upfront costs of about 2% to support optimized design will lead on average to life-cycle savings of 20% on total costs.**

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4. People, Organization and Culture

- Every change has to be driven and supported by the people involved, so E&C companies must focus on attracting, retaining and developing talent, and establishing a company culture conducive to innovation and improved skills.

- This is all the more necessary as the industry is traditionally regarded as **not particularly attractive to new talent** and, at the same time, it is in increasing competition for talent with other industries. To compound matters, it has an ageing workforce.

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5. Industry Collaboration

- E&C companies cannot **realize their full potential** on their own. The industry is one of the most fragmented in the world and relies on a seamless interplay of all participants along the value chain and throughout a project's life cycle.

- Companies need to enhance coordination and cooperation across the value chain, and jointly define standards and agree on common goals.

- Australia is duly pioneering the standardization of project alliance agreements and is adopting a model of cooperative partnership to reduce initial costs.

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6. Joint Industry Marketing

- To gain the support of society at large, the industry again needs to work collectively, along multiple dimensions. For example, it should promote itself as an attractive employer, and it should **engage local communities** by means of **participatory planning and ongoing community-involvement initiatives** during operations.

- A good example in that regard is the Considerate Constructors Scheme, a non-profit, independent organization founded by the United Kingdom's construction industry to **improve its image, share best practices and strengthen public awareness of the impact of construction on the environment.**

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7. Regulation and Policies

- In any given country, the public sector, and in particular the national government, can **enhance competition and productivity** by simplifying and **harmonizing building codes and standards.**
- By setting and **enforcing time limits for construction permits and environmental approvals,** governments can greatly reduce project delays.
- Ideally, governments should also **minimize barriers to competition at an international level.**
- And they should provide appropriate **support to academia and companies for developing technological innovations in construction.**

- The British government, for example, recently put the construction industry on the national agenda, in the hope of eventually positioning Britain at the forefront of global construction: among the specific targets to reach, for instance, is a 33% reduction in both the initial cost of construction and the whole-life-cycle cost of assets.

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Shaping the Future of Construction
8. Public Procurement

- Governments can also shape the industry by their actions as **key project owners.**

- The Crossrail project in London, for instance, systematically generates, captures and replicates innovative ideas and eventually translates them into practical innovations and industry standards. It also aims to raise the bar for other construction projects by making these ideas, technologies and practices available to the industry as a whole.

- Finally, the **issue of corruption on construction projects** can only be resolved by **creating a corruption resilient procurement environment, by implementing fair and transparent procurement procedures, and by establishing clear practices regarding the prosecution of corruption -** practices that address both the supply and demand sides of corruption.

1. Introduction: The Construction Industry – Time for a Transformation

1.1 The industry is crucial to society, the economy and the environment

Societal relevance

- ✓ Construction is one of the **first businesses that humankind developed,** and it continues to shape our daily life in unique ways.
- ✓ Virtually **all other businesses rely on the construction industry** to provide and maintain their accommodation, plants and infrastructure, and construction is a determinant of where and how almost everyone lives, works and plays.
- ✓ For nearly the entire population of the world, the **built environment heavily influences quality of life.** In the United States, for instance, people on average spend nearly 90% of their time indoors. So the building and the materials used in its construction and finishing have a major impact on the health and well-being of its occupants.

> "We shape our buildings and, afterwards, our buildings shape us."
>
> Winston Churchill, 1944

Economic relevance

- ✓ With total annual revenues of almost $10 trillion and added value of $3.6 trillion, **the construction industry accounts for about 6% of global GDP.** More specifically, it accounts for about 5% of total GDP in developed countries, while in developing countries it tends to account for more than 8% of GDP.

- ✓ The industry is expected to grow greatly in the coming years, to estimated revenues of $15 trillion by 2025. More than **100 million people are already employed today in construction worldwide.**

- ✓ Construction is a "horizontal" industry (like the Financial Services industry), **serving all industry verticals**; in other words, construction has considerable interaction with numerous other sectors, since value creation almost always occurs within or by means of buildings or other constructed assets.

- ✓ To mention a few, residential housing accounts for 38% of global construction volume; transport, energy and water infrastructure for 32%; institutional and commercial buildings for 18%; and industrial sites (from cement to automotive manufacturing) for 13%.

1. Introduction: The Construction Industry – Time for a Transformation

1.1 The industry is crucial to society, the economy and the environment

Environmental relevance

- ✓ The construction industry is the single largest global consumer of resources and raw materials. It consumes about 50% of global steel production and, each year, 3 billion tonnes of raw materials are used to manufacture building products worldwide.

- ✓ About 40% of solid waste in the United States derives from construction and demolition. Throughout the world, such waste involves a significant loss of valuable minerals, metals and organic materials – so there is great opportunity to create closed material loops in a circular economy.

- ✓ **As for energy use, buildings are responsible for 25-40% of the global total, thereby contributing hugely to the release of carbon dioxide.**

- ✓ Value therefore lies in **improving the quality of construction and the quality of materials used**, in contributing to a healthier indoor environment, increasing its sustainability and reducing its cost. Any endeavour towards this goal will generate welcome benefits – whether for families investing in their first private home or governments embarking on a giant infrastructure project.

Figure 2: Megatrends Shaping the Construction Industry's Future

Market and customers

Demand in developing countries

65% of the next decade's growth in construction will happen in emerging countries

Globalized markets

1 in 2 E&C companies plan to move into new geographies

Bigger, more complex projects

123km (76 miles) is the length of the Undersea tunnel that will connect Dalian and Yantai in China

Ageing infrastructure

1 in 3 German railway bridges are more than 100 years old

Massive financing need

$1tn annual investments are needed to close the global infrastructure gap

Sustainability and resilience

Resource scarcity

No. 1 consumer of global raw materials is the construction industry

Sustainability requirements

50% of the solid waste in the United States is produced by the construction industry

Energy and climate change

30% of global greenhouse gas emissions are attributable to buildings

Resilience challenges

3× as many disasters were reported last year as in 1980

Cyberthreats

90% of firms agree that information controls have an impact on front-line employees

Society and workforce

Urbanization and housing crisis

200k people are added daily to urban areas and need affordable and healthy housing

Health/comfort needs of citizens

2-5× higher than outside are the levels of volatile organic compounds found inside US homes

Talent and ageing workforce

50% of general contractors are concerned about finding experienced crafts workers for their workforce

Stakeholder pressure and organization

67k signatures were collected opposing the construction of the Stuttgart train station

Politicization of construction decisions

In 2011 the Portuguese government cancelled a 165km (103 mile) high-speed train line project as an austerity measure

Politics and regulation

Complex regulatory requirements

25 different procedures are required for a typical warehouse construction permit in India

Stricter HSE and labour laws

10% of the workforce in a public project in California had to come from the "otherwise unemployable"

Slow permit and approval process

$1.2tn of infrastructure could be added by 2030 if all countries committed to specific time limits for approvals

Geopolitical uncertainty

18 Turkish construction workers were kidnapped by militants in Baghdad in September 2015

Corruption

49% of survey respondents believe corruption is common in a Western European construction market

- ✓ -- Lack of innovation and delayed adoption. The lifeblood of any industry is research and development (R&D). The benefits of R&D, however, are long term, whereas the costs arise in the present. This mismatch is ill-suited to the project-driven business in which the construction industry operates, so R&D has received less attention here than in other industries.

- ✓ -- Informal processes or insufficient rigor and consistency in process execution. The processes typically adopted by construction companies regularly lack maturity. Companies often seem to put greater emphasis on defining the final product than on planning the actual construction process.

- ✓ -- Insufficient knowledge transfer from project to project. Although each construction project will have its own unique characteristics, the processes of construction itself are repeated in their essentials from project to project. Lessons learned from one project could therefore often be usefully applied to subsequent projects. Yet few companies have institutionalized such a process. Past experience is therefore often lost, and projects continue to rely heavily on the expertise of the individual project manager.

- ✓ -- Weak project monitoring. A related issue is the weak monitoring of projects, relative to other industries. In many manufacturing industries, for example, operations are continuously tracked and large quantities of data are collected. In that way, if something goes wrong, a car manufacturer, for instance, can quickly identify the root causes and implement remedies immediately and efficiently. Few construction companies are set up in this way.

- ✓ -- Little cross-functional cooperation. The conventional construction process is generally sequential, reflecting the input of the project owner, designers, constructors and key suppliers at different stages of the project. This set-up militates against sophisticated construction planning. Ideally, the knowledge of all stakeholders along the value chain should be fully exploited early on in the design and planning process, but that is seldom easy or even possible under current arrangements.

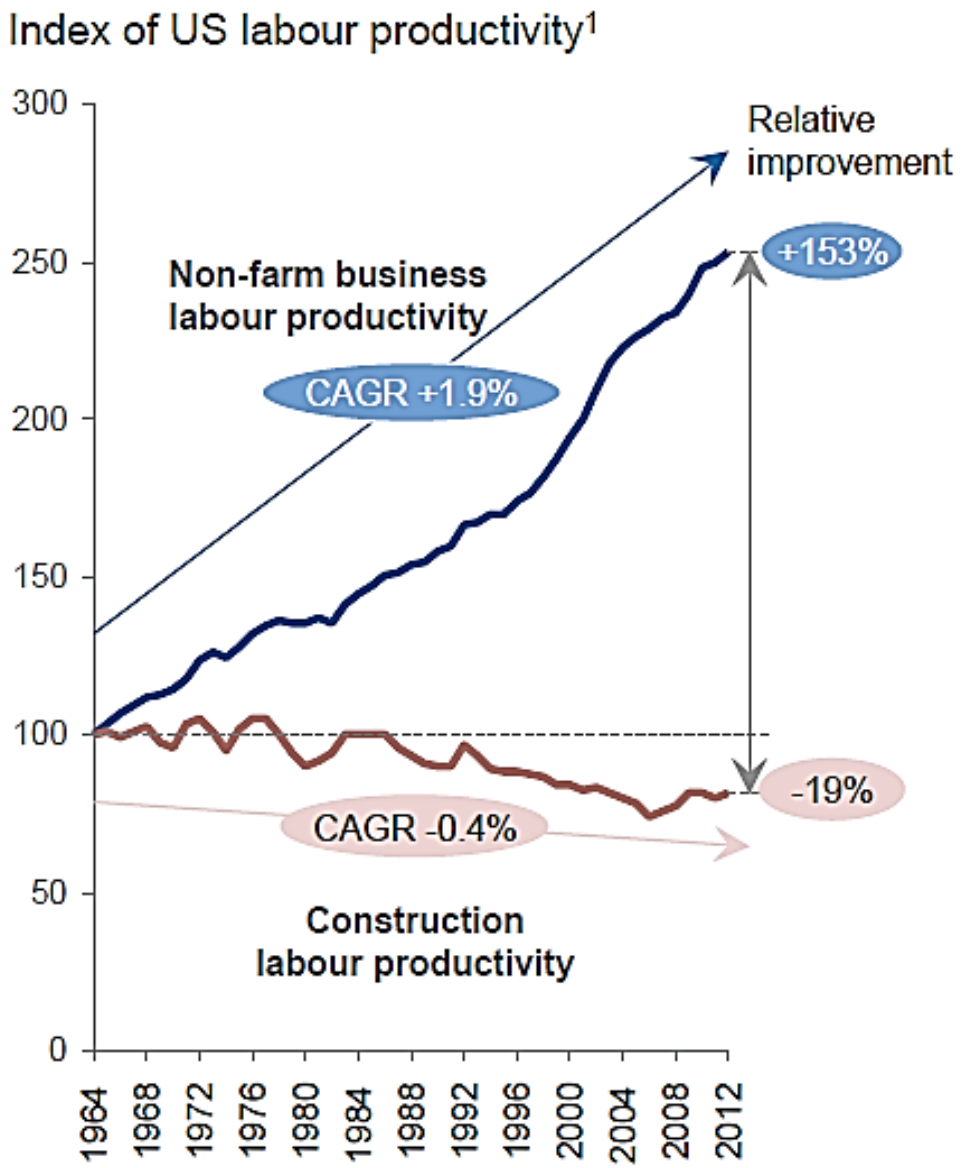
- ✓ -- Little collaboration with suppliers. For many large contractors, the purchasing strategy involves long-term relationships with key suppliers; nevertheless, the final decisions are often still made ad hoc, on a project-to-project basis. The problem is even more severe in smaller construction companies, where purchasing is almost exclusively project-based.

- ✓ -- Conservative company culture. The construction industry operates in a somewhat traditional environment and generally retains a conservative corporate culture. The widespread perception is, justifiably enough, that **construction companies are not sufficiently progressive or forward-thinking.**

- ✓ -- Shortage of young talent and people development. The image that people have of the construction industry as an employer is a relatively poor one, with **inadequate gender diversity** and **little job security (owing to the cyclical nature of the business).** As a result, E&C companies often struggle to attract talented recruits to their workforce. Relative to companies in other industries, construction companies engage less often and less effectively in internal people-development initiatives.

> "Looking at construction projects today, I do not see much difference in the execution of the work in comparison to 50 years ago."
>
> John M. Beck, Executive Chairman, Aecon Group, Canada

Figure 3: US Industry Productivity and Performance, 1964-2012[28]



Societal. A mere 1% reduction in construction costs would save society about $100 billion annually– a sum equal to the entire global cost of cancer drugs. In fact, the ambitions go far beyond that: the vision formulated by the UK government for 2025 is of a 33% reduction in the initial cost of construction and the whole-life-cycle costs of built assets.

Economic. The global shortfall in infrastructure capacity is expected to reach $15-20 trillion by 2030. Closing this gap could create up to 100 million additional jobs and generate $6 trillion a year in economic activity in the long run. Up to 30% of this boost could come from improvements to construction projects and to asset operations.

Environmental. By harnessing the capacity of the building sector, many countries can cut emission rates cost-effectively and achieve energy savings of more than 30%, according to the United Nations Environment Programme. The target set by the United Kingdom's construction industry for 2025 is a full 50% reduction of today's level of greenhouse gas emissions in the overall built environment.

Figure 4: Unique Construction Environment

The industry has unique characteristics ...

Multiple stakeholders with diverse interests/needs

— Three different project owners are involved in the construction of the Berlin airport. Delays of 10 years and cost overruns of about €5 billion are expected.

Project business and on-site construction

— According to the corporate strategy director of a major global E&C firm:
"Our product output is in the unit of 1."

High industry fragmentation

— The United States has 710,000 E&C companies; only 2% of them have more than 100 workers and 80% have just 10 workers or fewer.

Low profitability and capitalization

— Global listed E&C companies have a weighted average total shareholder return of only 5% and are consistently outperformed by most S&P 500 companies.

Highly cyclical and volatile business

— The Spanish construction market declined from a peak of €151 billion in 2006 to just €70 billion in 2012, and has still not fully recovered.

Unstable workforce

— In Canada, about 25% of workers whose construction jobs are terminated find their next job in sectors outside construction.

Unique construction environment

... and operates in a complex client context

Immature project definition and technical assessment

— Construction costs of the Hamburg Elbphilharmonie increased from €241M to €789M. "Almost all the extra cost resulted from planning that was insufficiently progressed at tendering time."

Over-preference for lowest price bid

— The launch of a 17km (11 mile) highway segment in Germany was delayed by six months, as one bidder raised objections to the tendering process – the lowest bid had not been chosen.

Insufficient or incremental funding

— Many US government contracts have an Availability of Funds clause that limits the government's liability to pay the full amount claimed.

Conservative clients

— A minor problem with an innovative rapid-hardening concrete during a night shift almost brought a public road project to a halt, as the project owner lost faith in the new material.

Increased risk transfer to contractors

— Emerging-market infrastructure investments with private participation, which often involve a transfer of risk to contractors, have tripled since 1995 and totalled $108 billion in 2014.

Complexity of contracts and dispute resolution

— 25 years ago, a typical contract consisted of about 50 pages; today it can easily exceed 1,000 pages and is packed with legal complexities.

Figure 1: Industry Transformation Framework

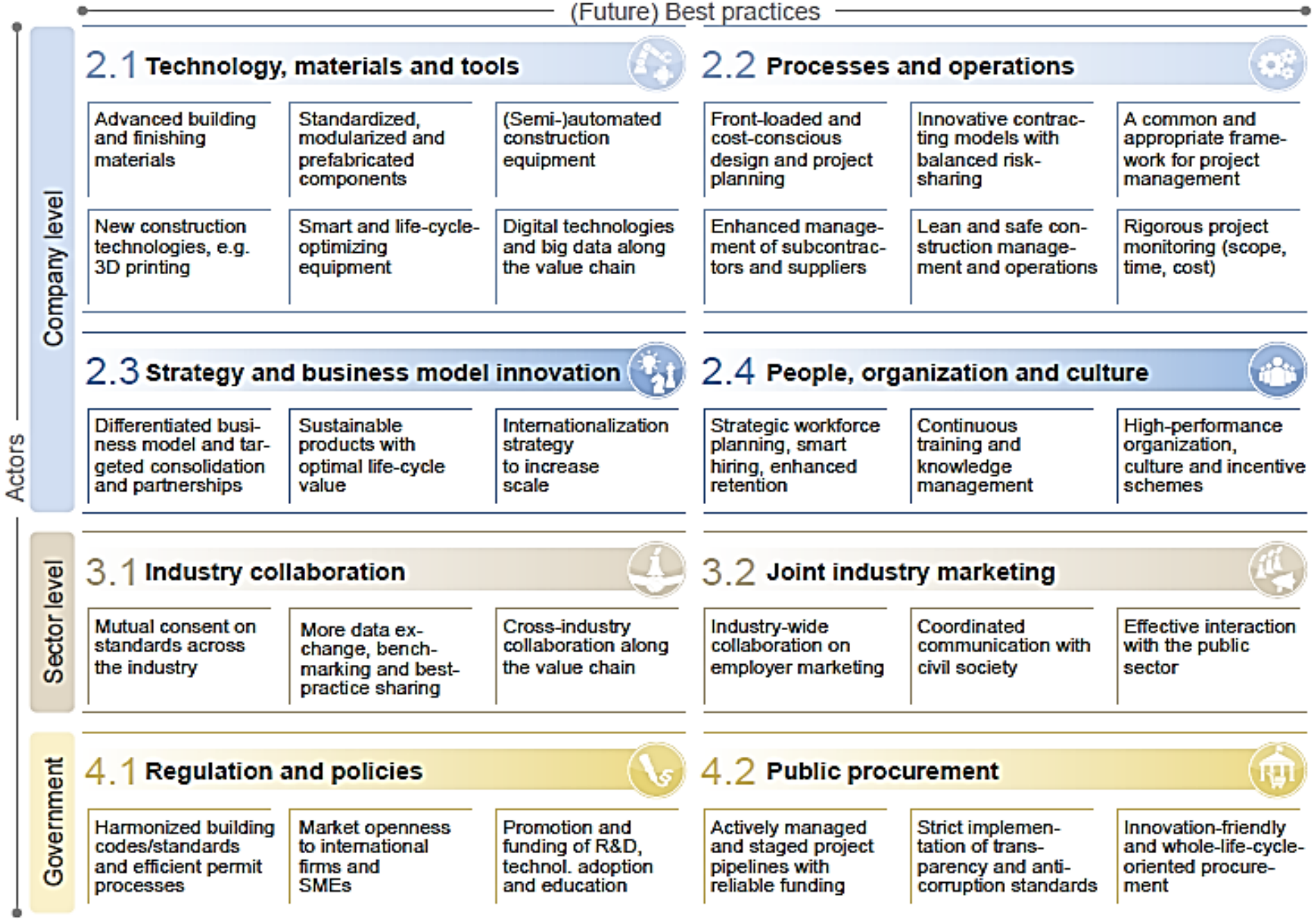
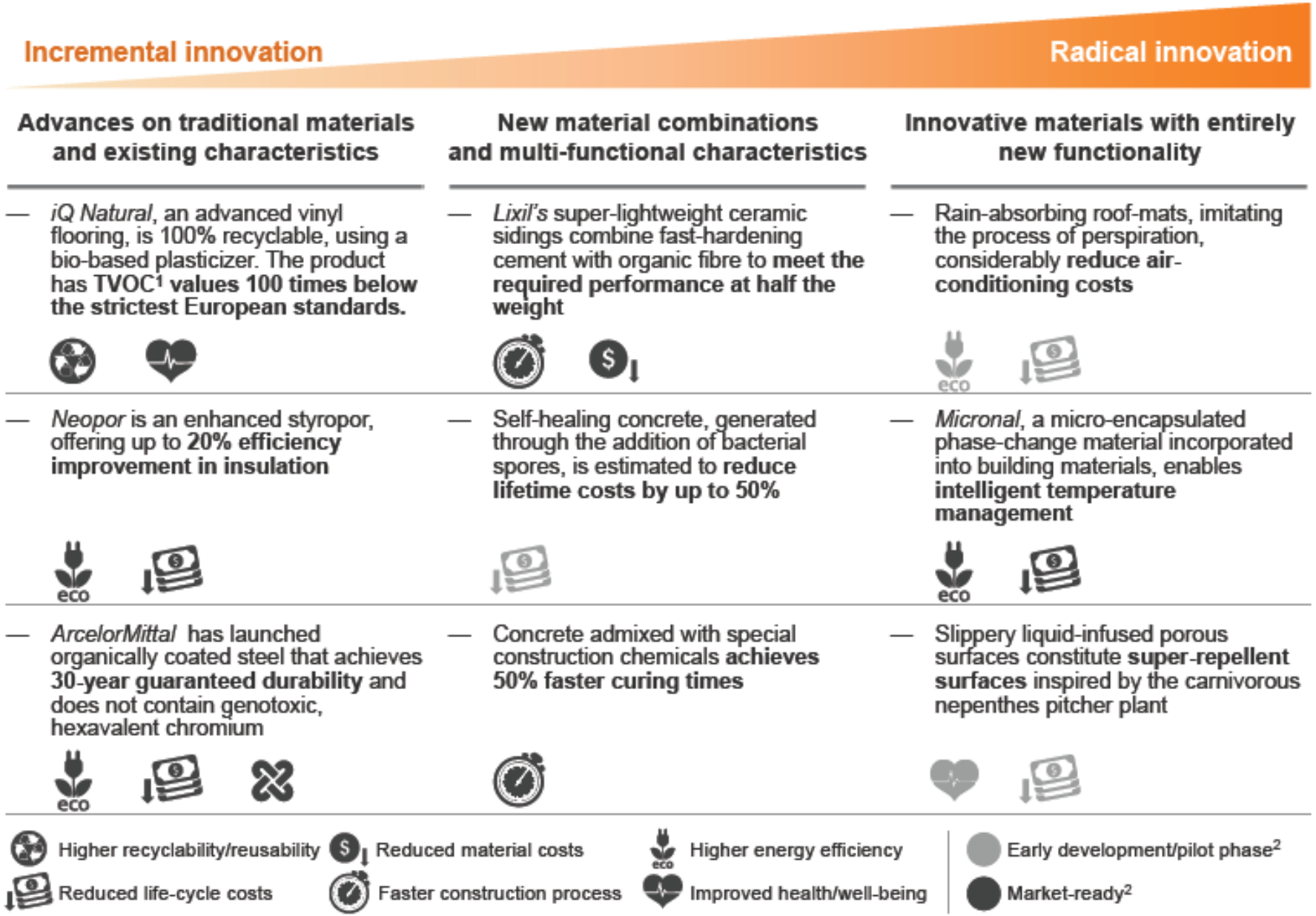


Figure 6: Examples of Advanced Building and Finishing Materials



Advanced Building and Finishing Materials

- ✓ Materials constitute an extremely powerful lever for innovation. The European Commission estimates that 70% of product innovation across all industries is derived from new or improved materials. With approximately one-third of construction cost attributed to building materials, the scope for applying advanced building materials (ABMs) is considerable.

  EXAMPLE: Fluor has built up an internal team of experts on concrete to advise the client at an early planning stage, to develop a foundation of data based on experience and to create a convincing business case for greater use of innovations (such as 50%-faster-curing concrete) in the market.

  EXAMPLE: The United States Army Corps of Engineers (USACE) validates new technologies (such as cross-laminated timber), whether in its own research labs, in demonstration projects or in collaboration with academia. Once a new technology has met USACE requirements, its value can be communicated internally in multiple ways to ensure broad awareness. Additionally, when appropriate, such technologies can be specifically incorporated into design guides or specifications.

EXAMPLE: BASF and Arup have jointly developed an app for architects, engineers and project owners to calculate the energy savings achievable from the latent-heat storage system Micronal.

Standardized, Modularized or Prefabricated Components

- ✓ Productivity in construction could receive a substantial boost from standardization, modularization and prefabrication. The standardization of components brings many benefits, including a reduction in construction costs, fewer interface and tolerance problems, greater certainty over outcomes, reduced maintenance costs for end-users, and more scope for recycling.

- ✓ Modularization adds to the advantages of standardization, by increasing the possibilities for customization and flexibility, and helping to realize the potential of prefabrication in a factory-like environment.

- ✓ Prefabrication would increase construction efficiency, enable better sequencing in the construction process and reduce weather-related holdups; by such means, it becomes possible to reduce a project's delivery times and construction costs relative to traditional construction methods, and also to create safer working environments.

Standardized, Modularized or Prefabricated Components

- ✓ Among the typical obstacles to its acceptance are:
  - × Poor image, due to misconceptions about quality, price and the potential for individualization
  - × Client demand for individual solutions, which discourages the use of standardized processes and components
  - × Limited experience of the application of prefabrication – in high-rise projects, for instance
  - × The increased risk involved in committing to particular off-site suppliers, especially since the market is not yet well developed and alternatives are not instantly available
  - × Underutilization of the prefabrication factory space, due to the customized and irregular nature of construction demand
  - × The high cost of transportation, especially in cases where the distance between the factory and site is large or where the transport links are inadequate, as well as community opposition to the transportation of oversized components
  - × Problems in handling large prefabricated components in space-constrained construction sites
  - × Technical specifications from project owners: in Spain, for example, public projects

Standardized, Modularized or Prefabricated Components

- ✓ Further develop modular construction systems, working jointly with suppliers – to improve applicability, for instance, and generate systems to meet the demand for affordable high-density housing in urban areas.

  EXAMPLE: Fluor has applied modular concepts from offshore construction to onshore projects such as chemical plants, and has thereby achieved capital expenditure reductions of 20-40%. In collaboration with the supplier, it has included cable harness in its modular systems, resulting in further productivity improvements.

Standardized, Modularized or Prefabricated Components

- ✓ Introduce an economic and logistical assessment of these technologies in the planning process and tailor on-site construction processes to the use of prefabrication components or modular systems; work of this kind can help greatly in realizing the full productivity potential of prefabrication.

  EXAMPLE: Broad Group China, in cooperation with ArcelorMittal, is using a system of modular building components that enables very speedy construction: a 57-storey building was built in only 19 days by moving 90% of the construction work to the factory.

- ✓ Collaborate with customers and educate them on the advantages of prefabrication; take into account the opportunities for repurposing or post-installation adjustments, to meet society's future needs

  EXAMPLE: MQ Real Estate developed, in collaboration with hotel operators, a scalable modular apartment system that enables firms to build non-permanent housing or hotels within weeks in dense urban areas, to cope with seasonal peaks in demand and exploit temporarily vacant areas much more efficiently

Standardized, Modularized or Prefabricated Components

- ✓ Apply new construction concepts
  - ✓ EXAMPLE: Skanska has developed a new construction concept known as “Flying Factories”, which are temporary factories set up close to construction sites; they apply “lean” manufacturing techniques and employ local semi-skilled labour. The advantages include a reduction in construction time of up to 65%, a halving of labour costs and a 44% improvement in productivity relative to on-site assembly, while still upholding the construction industry’s importance as a local employer.

Semi-Automated Construction Equipment

- ✓ As more and more processes in the construction industry are mechanized, machinery has acquired a central role and has proved to be a strong driver of productivity gains.
- ✓ Excavators and bulldozers make it quick and easy to move large amounts of earth; drilling rigs and piledrivers facilitate underground engineering; conveyers and pumps optimize concreting work; and mobile cranes lift and position heavy loads.
- ✓ Leverage new technologies by integrating physical and digital systems
  - ✓ EXAMPLE: Komatsu, a Japanese manufacturer of construction equipment, is developing automated bulldozers incorporating various digital systems. Drones, 3D scanners and stereo cameras gather terrain data, which is then transmitted to the bulldozers; these are equipped with intelligent machine-control systems that enable them to carry out their work autonomously and thereby speed up the pre-foundation work on construction sites, while human operators monitor the process. On mining sites, autonomous haul trucks are already in common use.

Semi-Automated Construction Equipment

- ✓ Create preconditions for automation early – as early as the design and project planning phase. That can be done by increasing the proportion of prefabrication and modular systems, since **automation works best with standardized components and processes.** Better upfront planning and technical preparation in setting up construction sites is also needed.

- ✓ Establish industry standards – for communication protocols, for instance – so that automated and interoperable equipment can be applied widely to overcome the fragmented and multi-stakeholder nature of construction processes

- ✓ Make better use of existing equipment – for example, by adopting new business models (as described in Figure 7)

Figure 7: New Deployment Models for Construction Equipment[43]

Improve availability of individual equipment	**Continuous monitoring** and preventive maintenance and repair of construction equipment result in **better availability of individual equipment**		Volvo Construction Equipment has launched a programme based on a machine-tracking information system that **aims to identify problems before they occur, improving equipment uptime**
Enhance utilization of a company's entire fleet	Central fleet management systems and the tracking of vehicle use **increase the utilization of equipment across the firm**, e.g. by identifying ways to save fuel costs		Teletrac provides GPS fleet-tracking software with a real-time view and analytics, resulting in **reduced fuel consumption of up to 30%** – for instance, by avoiding unauthorized vehicle use
Use equipment better across companies	Various forms of equipment leasing and sharing help to **distribute capacity more efficiently** across the industry, e.g. — traditional leasing — "power by the hour" — "pay by intensity" — B2B sharing platforms		A large construction equipment manufacturer has invested in the start-up Yard Club, which helps owners of heavy equipment to rent out idle machines to other businesses, thereby **reducing the cost of owning equipment**

New Construction Technologies

- ✓ The **development of 3D printing** is expected to have a disruptive impact on the construction industry. The technology enables the production of **purpose-built shapes** that **cannot be produced by any other method;** it promises **productivity gains of up to 80% for some applications,** together with an important **reduction in waste.** Construction time for some buildings could shrink from weeks to hours, and customized components could be provided at much lower cost.

- ✓ However, 3D printing in the construction industry is **still at an early stage of development.** Several issues persist, including resolution problems (large-scale printing often produces rough, chunky results), a trade-off between scale and speed (big printing remains slow – standard 3D printers are constrained by their size), and high costs.

- ✓ At present, 3D printing is still mostly **applicable to low-volume, high value parts.** It remains to be seen how quickly companies will overcome the main technological challenges, and whether they will be able to bring down costs and achieve economies of scale.

EXAMPLE: In a project on 3D-printed steel components, Arup achieved a 75% weight reduction and 40% reduction in materials compared with traditional production methods

EXAMPLE: The Skanska 3D Concrete Printing project aims to demonstrate that 3D printing can be used to manufacture concrete objects in shapes that were unfeasible through traditional casting methods.

EXAMPLE: MX3D, a Dutch start-up working with partners such as ArcelorMittal, ABB and Autodesk, has developed an external six-axis 3D printing robot capable of printing lines in mid-air, and has used it to print a footbridge across an canal in Amsterdam.

EXAMPLE: WinSun (China) has been building 10 houses a day by using 3D-printed building components, and has concluded a deal with the Egyptian government for 20,000 single-storey dwellings leveraging this technology.

New Construction Technologies

- ✓ Few other new construction technologies look capable of making a comparable impact, but structural bonding is worth mentioning. It offers certain advantages over conventional welding, such as greater design freedom, a more uniform stress distribution and lower heat input; so far, however, its applications in construction are limited, owing to ongoing concerns about structural integrity and fire safety. One other new construction technology has considerable potential: instead of constructing immoveable concrete buildings, companies could create **lightweight block-like structures that can be relocated.**

EXAMPLE: An army of robot-crane hybrids (called “crabots”) will be assembled to build Google’s new headquarters in California. They will lift prefabricated components such as walls and heavy furniture into place beneath vast glass canopies.

Smart and Life-Cycle-Optimizing Equipment

- ✓ The concept of smart building is gaining in popularity. This is in part due to technological advances, which are driving down the cost of sensors, data storage and computing services. At the same time, potential customers are showing increased interest, attracted by the widening adoption of connected devices, and are demanding greater energy efficiency in buildings and improved safety and convenience.

- ✓ As for the owners or end-users of buildings, they stand to gain several benefits: reduced operating costs, through a likely 20-40% reduction in energy usage; greater comfort, thanks to improved lighting and temperature controls, for instance; and increased operational efficiency, partly by means of remote servicing.

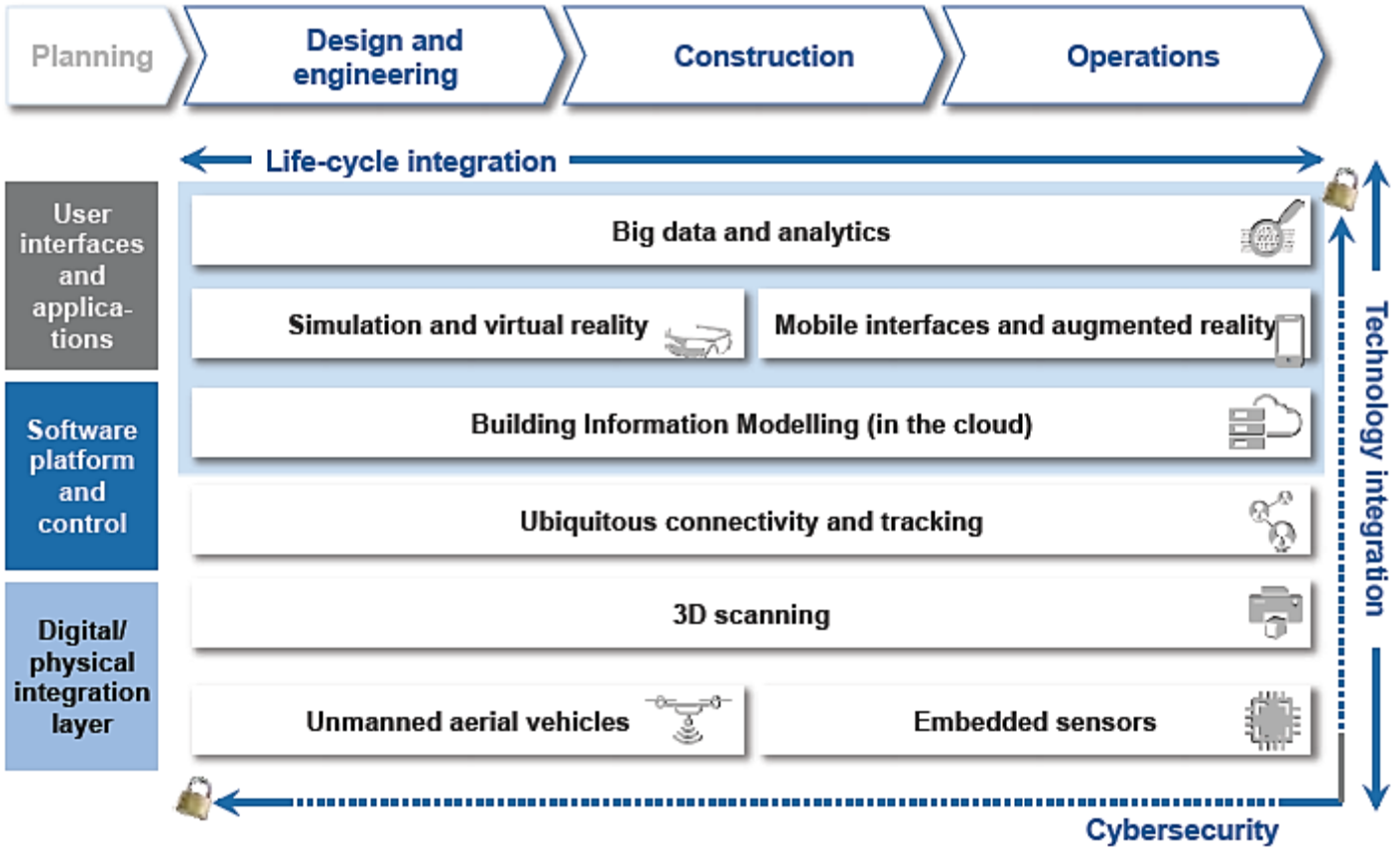
- ✓ This development affects all built assets and sectors. In the Energy sector, for instance, smart meters and demand response are emerging.

- ✓ In Transportation, smart technology enables smart transport and parking. In Housing, connected and smart devices are gaining popularity. And by interconnecting people, machines and data, smart-building equipment is contributing powerfully to the optimization of the O&M of buildings and other constructed objects.

EXAMPLE: The South Korean city of Songdo – which claims to be the largest private real-estate investment in history – is a greenfield initiative, combining "smart" technologies across all sectors to create an environmentally sustainable, economically viable and liveable city.

EXAMPLE: Skanska and its partners are pioneering the wireless monitoring of buildings, using sensors to record data (such as temperature and vibration), and wireless equipment to store and transmit this data. Data analytics are applied to determine the implications of any changes in the sensor readings. These smart-equipment technologies have the potential to reduce unexpected failure by 50%, improve building-management productivity by 20-30% thanks to less need for inspections, and improve the building's energy performance by 10% over its lifetime.

Figure 8: Digital Technologies Applied in the E&C Value Chain[48]



Digital Technologies and Big Data along the Value Chain

- ✓ Digitalization – the development and deployment of digital technologies and processes – is central to the required transformation of the construction industry. Innovations of this kind enable new functionalities along the entire value chain, from the early design phase to the very end of an asset's life cycle at the demolition phase.

  EXAMPLE: Atkins has implemented advanced parametric design techniques for detailed design "optioneering" in the water infrastructure industry. That has made it possible to provide 22 design options in one day, a 95% time improvement on traditional design methods for similar results.

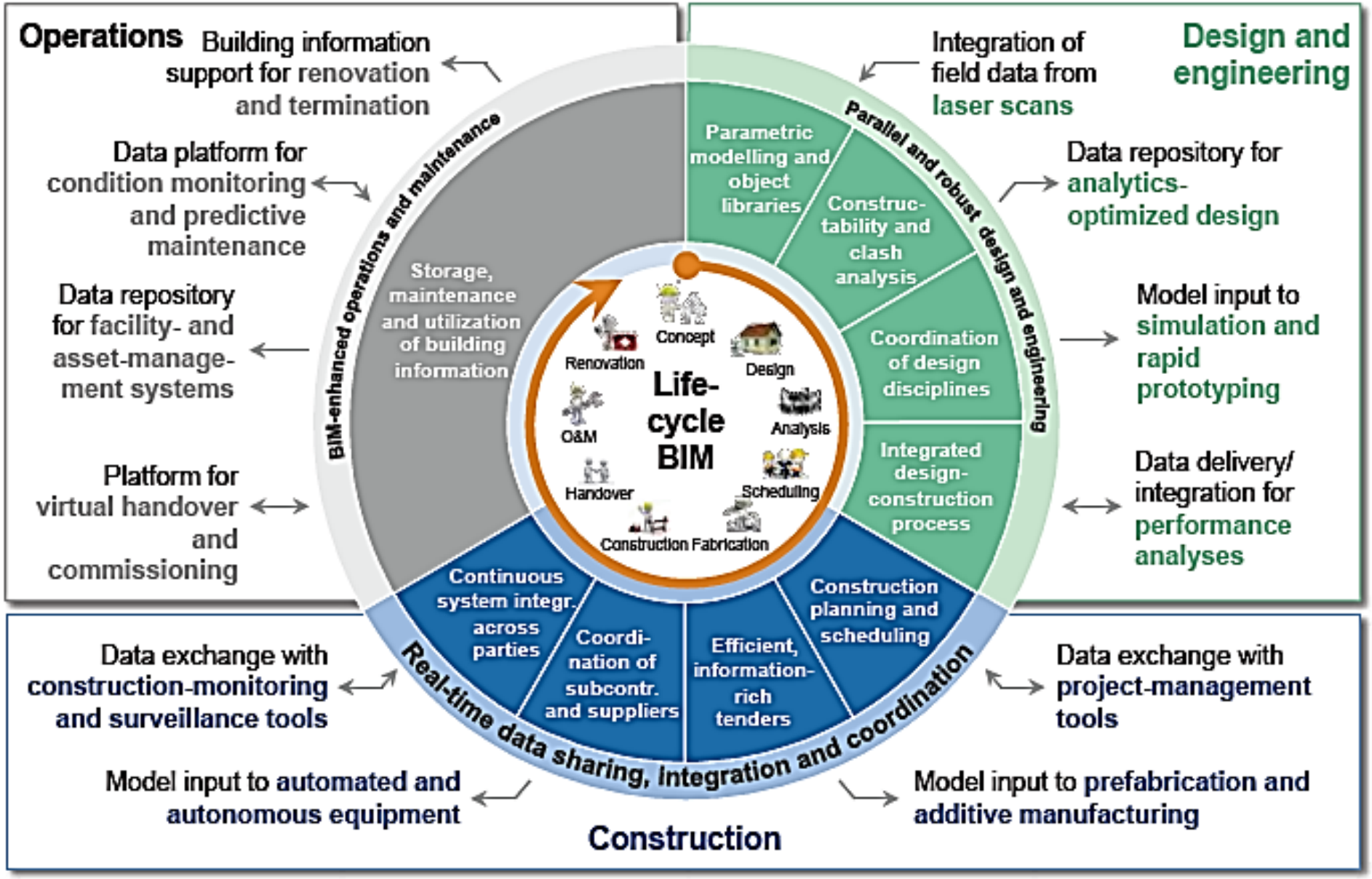
  EXAMPLE: *Arup* combines various data-collection methods, including mobile surveys, security-camera footage and traffic-flow reports, for improved decision-making in the design of residential projects.

Companies can refine their monitoring of projects by using drones and embedded sensors to enable real-time communication and to track people, machines, components and the construction process itself. 3D scanners build digital models of existing buildings; they can also detect any deviations very quickly during the construction process, and can enable deformation monitoring.

EXAMPLE: Skanska is developing a Tag & Tack system, pioneering the use of radio frequency identification (RFID) tags and barcodes on products and components in construction projects. By facilitating real-time monitoring of delivery, storage and installation in this way, the new system is achieving reductions of up to 10% in construction costs. These digital technologies also facilitate the adoption or enhanced application of many of the other innovations, such as prefabrication, automation and 3D printing, and should help to improve various processes in the industry, such as front-loaded design and planning or project management in general. For instance, advanced project planning tools use complex mathematical modelling to optimize the allocation of construction staff and individual roll-out functions for infrastructure projects.

- ✓ To elaborate on one further digital tool: Building Information Modelling (BIM) is gaining currency as a platform for central integrated design, modelling, planning and collaboration.
- ✓ BIM provides all stakeholders with a digital representation of a building's characteristics – not just in the design phase but throughout its life cycle. It presents several important opportunities, as shown in Figure 9.
- ✓ Above all, BIM facilitates collaboration among all stakeholders – from early design through to O&M and even to the decommissioning phase – and thereby holds out the promise of large efficiency gains.
- ✓ All stakeholders can contribute information to and extract information from the central model. By providing a lifelong view of construction projects, including the TCO, it offers owners great benefits in the commissioning and operations phase, and enables new business models, particularly in asset management.
- ✓ Such a life-cycle BIM eventually produces a continuous build-up of know-how, by enabling a seamless flow of information across different construction phases and stakeholders.
- ✓ By providing a neutral and unbiased view, BIM can also contribute greatly to creating a level playing field in this regard, and more effective dispute resolution.

Figure 9: Applications of BIM along the E&C Value Chain[50]



EXAMPLE: Atkins is applying advanced digital and high-tech solutions to high-hazard operations, such as the retrieval of radioactive waste or the transport of spent nuclear fuel. It uses 3D laser scanning and 3D cameras to provide an accurate as-built status of the asset profile up front, and thereby increases confidence in the design and facilitates delivery. Virtual reality and augmented reality help to engage stakeholders, by clarifying the design and indicating progress throughout the project's life cycle; they also help to reduce the time that operators and surveyors have to spend in high-hazard or high-dose areas. 3D BIM facilitates clash detection and – by also incorporating programme details, cost constraints and asset-management information – it optimizes the use of data throughout the project's life cycle without loss, contradiction or misinterpretation. By learning from experience and implementing its solutions adeptly across the full life cycle of the project, Atkins can achieve as much as a 20% reduction in the time needed for completing a project, and up to 16% in cost savings.

- ✓ Prior to achieving large-scale implementation and all the potential benefits of BIM, however, various obstacles must be overcome:
  - × Implementing BIM, within a company and industrywide, requires a considerable build-up of expertise, especially appropriate employee training and substantial IT upgrading. Small companies will find that especially challenging, as they might struggle to afford the upfront investments.
  - × Technological standards have to be in place and interoperability must be ensured, so that the various stakeholders can share information and cooperate on planning.
  - × Project owners will be slow to adopt the technology until they acquire a greater understanding of the benefits of BIM for them.
  - × In BIM, data is created and shared in a more collaborative way, which leads to further issues regarding data ownership and liability.
  - × The benefits of large-scale BIM can only be realized when all participants along the value chain get involved; without this interlinking effect, there is little benefit for the first movers.

- ✓ Build up the digital expertise and spread it across the company. E&C companies have not exactly been a magnet for "digital natives" up to now, and they really need to attract a critical mass of such talent. Companies should set up a central innovation department and/or a BIM department to institutionalize digital endeavors and to expand the digital knowledge base more quickly. Larger companies should appoint a chief technology officer. Make sure that all regionally dispersed divisions and teams are part of the transformation.

  EXAMPLE: Skanska established a robust network of BIM and Virtual Design and Construction professionals, who are committed to enhancing project planning, execution and delivery through the implementation of new technologies and innovative processes. Within this network is a core group of experts who are responsible for developing standards, training staff, providing project support, sharing best practices and improving the way the company works.

- ✓ Establish the technological foundation and complement digital capabilities through third parties where needed. Identify and prioritize the most relevant digital technologies according to their maturity level as well as business and market needs. Invest in the requisite software and hardware tools and IT infrastructure. Make sure to gain access to and/or ownership of relevant data generated along the building life cycle.

- ✓ Take on pioneering roles and share expertise to encourage the adoption of BIM among smaller companies, though without overstraining them or expecting equivalent commitment from them

  EXAMPLE: Arup set itself the goal of using BIM on more than 80% of its design projects by April 2015, and has developed a diagnostic tool measuring the degree and success of a project's use of BIM. The company has made the tool available to other companies.

- ✓ For technology suppliers:

- ✓ Strengthen the core and seek to overcome interoperability issues and improve interface definitions. Strengthen the product offering for the traditional target group of designers and engineers, by adding functionalities and modelling dimensions, improving usability and simplifying reuse of the vast amount of data from past projects. Agree on standards to improve the interoperability of different BIM systems and integrate all disciplines. Eventually, get the 3D models connected to the Enterprise Resource Planning systems also, in order to create a single source of authoritative data across all relevant systems.

  EXAMPLE: Autodesk and Bentley Systems are working together to enhance interoperability between their portfolios of construction software.

- ✓ Educate project owners on the advantages of using BIM, and encourage them to use it early in the planning process. Launch initiatives, such as value proofs, joint pilots and digital-skills training courses for clients, to speed up the adoption of new digital technologies.

- ✓ Expand into construction and underserved markets by adapting to the specific needs of construction companies. Address new links in the value chain and/ or new market segments. Offer operators a clearer value proposition for their use of the BIM model after handover. Ensure that everything is working smoothly at the interfaces between BIM and adjacent facility- and asset-management systems and building-automation systems. Provide holistic solutions for the entire design build-operate life cycle.

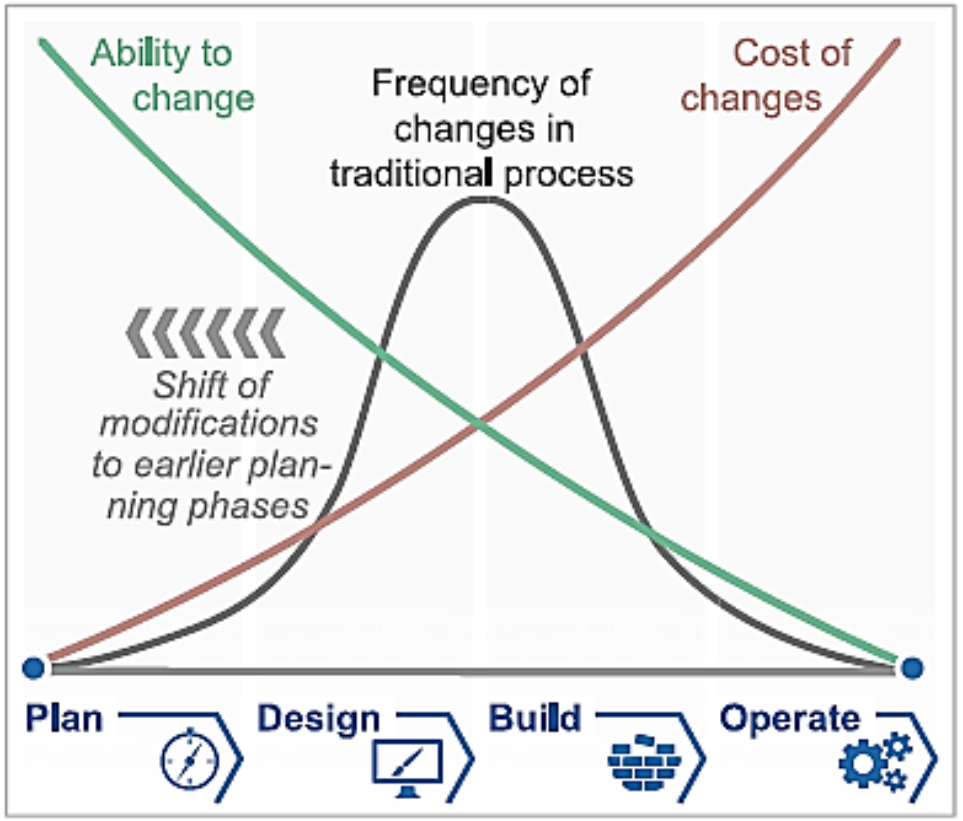
Front-loaded and Cost-conscious Design and Project Planning

- ✓ From a TCO perspective, construction's share of the total cost over the lifetime of the asset can be as high as 10-50%, while the O&M costs may account for 40-80%. These two major cost components are largely determined early on, during the design and engineering phase. At this early stage, it is still relatively easy and inexpensive to make changes: hence the case for smart front-loaded design and engineering, as highlighted in Figure 10. By making whole-life-cycle-conscious decisions and finding the right innovative solutions, project planners can create significant value.

- ✓ To achieve substantial improvements in construction productivity and to reduce O&M costs, companies need to ensure that, during the design and engineering phase, they keep the actual construction process in mind, as well as the final operations phase. This early phase should ideally incorporate the knowledge of all companies along the value chain – the main contractor, subcontractors, suppliers, and later on the asset's operator, owner and maintenance firms. From the outset, stakeholders, especially of large and complex construction projects, should give prominence to project planning and scoping – for instance, by conducting sophisticated needs assessments and feasibility analyses. Alarmingly, projects sometimes go to tender and even begin construction before detailed scoping and planning have taken place.

Front-loaded and Cost-conscious Design and Project Planning

Figure 10: Cost of Changes in the Construction Life Cycle



Front-loaded and Cost-conscious Design and Project Planning

Companies across the value chain can enhance frontloaded design and project planning by adopting the following procedures:

- ✓ Highlight and plan adequately the construction and O&M phases (do so during the design and engineering phase) and continuously analyse the impact of all design and planning decisions. Apply Design for Manufacture and Assembly (DfMA) – that is, design that facilitates the manufacture and assembly of components. And consider, as soon as possible, what the optimal O&M regime might be, and how that might influence the asset's requirements, the design and the eventual handover of information to the operators.

  EXAMPLE: Fluor has achieved a noticeable reduction in direct scaffolding costs by starting its pre-planning of the construction process very early, in the early design and engineering phase.

EXAMPLE: Atkins embraced the opportunities offered by DfMA in a Priority Schools Building Programme in the United Kingdom. The measures included investing in off-site manufacturing capability, using BIM to speed up and coordinate aspects of design, using common specifications and details across projects, and adjusting the business model to produce more detailed information earlier in the process. As a consequence of these innovative measures, construction time decreased considerably and safety on the construction site improved greatly; the project cost and lifetime cost (such as energy consumption) were reduced and became more predictable; and the project as a whole proved much more environmentally and socially sustainable (causing less neighborhood disruption, for example) than if more traditional approaches had been adopted.

- ✓ Ensure successful know-how transfer across phases. This could be achieved by transferring construction experts temporarily to the engineering team, or by using the same project manager across both the engineering and the construction sub-phases. It usually entails new delivery methods with early involvement of the contractor, or an approach where a single company is responsible for design, engineering and construction.

Front-loaded and Cost-conscious Design and Project Planning

- ✓ Hire external experts to conduct independent design reviews and to ensure that the construction process is given appropriate weight in the early design phase. For example, a specialized engineering company provides services that optimize the conceptual design of wind parks; the methods include conducting an economic assessment of a park's layout and the energy efficiency, and reviewing (at an early planning stage) technical parameters like terrain conditions.

- ✓ Conduct value engineering in consultation with all stakeholders

  EXAMPLE: Contractors for a large infrastructure project in Florida, which was initially budgeted at $250 million, identified cost savings of up to $70 million by means of a value-engineering approach. Multidisciplinary teams reviewed the project and recommended alternative designs, materials and methods – such as eliminating unwarranted illumination, reusing current roadways and constructing a multi-use path within an existing pavement rather than acquiring a new one.

Innovative Contracting Models with Balanced Risk Sharing

- ✓ To realize the full potential of front-loaded and cost-conscious design and project planning, it is crucial to get all relevant parties engaged and well coordinated early on. All those parties involved in the construction process – owners, contractors, subcontractors and suppliers – obviously have a vested interest in on-time performance and on-time payment, and would benefit by shifting away from the classic sequential design-bid-build approach to a more integrative approach.

- ✓ Construction companies could take on new roles by applying innovative contracting models. In a design-build (DB) approach, for example, a single company could – through a single contract with the project owner – undertake to provide all design and construction services and therefore contribute to better trade-offs between design and construction decisions. PPPs can accelerate infrastructure programmes by tapping into the private sector's financial resources, as well as its skills in designing, building and operating infrastructure on a whole-life-cycle cost basis. An early contractor involvement (ECI) model integrates design development and construction planning by including a contractor in the early planning stages. In the first phase, the contractor advises on project engineering and planning, and a target price is agreed upon; if that target price is met, the contractor will be retained for the construction phase as well.

Innovative Contracting Models with Balanced Risk Sharing

EXAMPLE: The contractor in a pilot project of six windmills in the United Kingdom participated in an ECI model when the project's feasibility became doubtful owing to the soaring price of the required steel. The contractor not only helped to find a cost-effective design alternative but also developed, together with the crane supplier, a bold lifting solution with a reduced counterweight.

- ✓ Companies could also begin by developing and applying smart collaboration models. Unfortunately, any new, collaborative approach increases the risk of conflict between the partners as new routes are embarked on and clear historic "borders" blur. Witness the recent increase in the length and cost of stakeholder disputes: in 2014, each dispute had an average value of $51 million and lasted 13 months. Certain models of cooperative partnerships, however, can reduce the number of such conflicts or at least accelerate their resolution. They do so by establishing a culture of trust and mutual respect among the participants. Figure 11 provides a non-exhaustive list of measures: their applicability varies according to the type and set-up of the project.

Innovative Contracting Models with Balanced Risk Sharing

Figure 11: Elements of a Cooperative Partnership[61]

Project culture		Project charter with common project goals	Transparent financials ("open books")	Co-location of teams ("big rooms")	Common data platform (e.g. BIM)
Tendering and contract		Choosing most efficient, not cheapest	Multi-party contract with clear accountabilities	Early involvement of key participants	Prudent management and appropriate allocation of risk
Incentive mechanisms		Alternative cost models, such as target cost	Incentives for cost optimization	Premium for early project delivery	Shared risk/reward ("pain share, gain share")
Conflict resolution		Collaborative decision-making and control[1]	Internal dispute resolution via negotiation	Third-party mediation and conciliation	Decision by adjudicator or arbitrator

Innovative Contracting Models with Balanced Risk Sharing

- ✓ Companies should increasingly use models based on these principles. One such model is an "alliance" between a project owner and private-sector parties for delivering one or more construction projects, where the parties generally have to **work together as an integrated, collaborative team.**

- ✓ Another such model is integrated project delivery (IPD), with core elements such as target cost pricing, shared risks and rewards, common collaboration platforms like BIM, and cross-functional groups.

EXAMPLE: A study by the Australian Department of Treasury and Finance found that companies achieved significantly greater value for money when implementing alliance-based delivery methods in infrastructure projects. The reason is that "alliancing has demonstrated its ability to avoid disputes, improve non-cost outcomes and commence projects earlier than by traditional methods."

Innovative Contracting Models with Balanced Risk Sharing

EXAMPLE: The California Pacific Medical Center used an IPD agreement to coordinate the main participants in a project. The project's owner, architect, project designer and qualified construction manager had a shared risk/reward pool and waivers on liability. The cost of IPD preconstruction services was well worth it, as significant savings followed, and the project achieved a 200% return on investment. The savings can be attributed mainly to the target value design process, which made all design-team members accountable for creating maximum value within the target cost. Further success factors were the co-location of teams, and the compulsory use of BIM by all IPD team members, including trades.

Innovative Contracting Models with Balanced Risk Sharing

- ✓ In any of those innovative contracting models – whether DB, ECI, PPP, "alliances" or IPD – it is always important to **improve accountability** and **manage risks effectively.**

- ✓ These goals can be **achieved by making information available to all stakeholders at an early stage**, by ensuring prudent risk-allocation among stakeholders and by encouraging a common risk-management strategy.

- ✓ World Economic Forum E&C Governors and Risk Task Force members identify the key levers as follows:

1. control the level of risk exposure by **allocating risk to the party that can manage it best**, and understand emerging risks better
2. secure **fair compensation for the risks**, by understanding their true value, and educate all stakeholders about them
3. **control the cost of risk management,** by acquiring the capabilities needed economically and by sharing specialist resources

A common and appropriate Framework for Project Management

The execution of construction projects all too often relies heavily on the expertise or even intuition of the individual project manager. Even though no two construction projects are identical, the "lessons learned" from any one project can prove very helpful when applied to another. Ideally, companies should institutionalize these lessons, so that project management can undergo continuous improvement across projects.

To establish a common framework for project management in this way, construction companies should consider taking the following steps:

1. Collect and consolidate project-management data. Among the requirements here are an improved project monitoring system and a strong reporting tool, enabling the continuous collection of project data.
2. Standardize the identification of best practices. This includes evaluating the performance of individual projects and developing a portfolio of best-practice processes to accommodate a variety of different projects.
3. Make sure that the best-practice standards actually get applied at the project level. If necessary, educate project managers and other important decision-makers in the appropriate processes, or make the best practices mandatory.

EXAMPLE: A mid-sized Swedish construction firm reduced the choice of building materials for its on-site project managers, so the workers no longer needed to be familiar with so many components, and errors diminished accordingly.

A key facilitator in implementing these steps is a set of company-wide software tools. These tools will help in connecting islands of information, making information easily available and simplifying actual project management (by providing support for scoping, scheduling or costing).

A final note in this regard: formerly, the term "project management" was often used to refer merely to the execution component of a construction project, and the emphasis was mainly on the project manager's ability to deliver in line with budgets, timelines and specifications. Modern project management, however, concerns itself with the planning and strategic components as well; it engages with the "front end", for instance, as the source of particular benefits and value, and assigns great importance to the interdisciplinary, interpersonal and integrative aspects of the project manager's role.

Enhanced Management of Subcontractors and Suppliers

- ✓ In many developing countries, purchasing materials and components poses a serious problem – namely, the shortage (often temporary) of some critical resources, such as cement or steel.

- ✓ In complicated projects, as in the petrochemical industry, companies – even in developed markets – often have to import components from other countries, and the delivery status and current location of those components may be unclear. As a result, projects are delayed; alternatively, companies will build up large stocks of some materials in an effort to compensate for an unreliable supply chain, and will thereby tie up large amounts of working capital.

- ✓ It is crucial to integrate suppliers and subcontractors more effectively, and that task falls mainly to the main contractor. Various measures are available, not just in the planning phase but throughout the entire project. The goal should be to establish an agile supply chain able to respond flexibly and promptly to changes in the external environment (weather-related hold-ups, changes in scope and schedule, regulatory changes) and integrate well with other parts of the business in addition to procurement. The supply chain as a whole should be regarded as a business partner.

Enhanced Management of Subcontractors and Suppliers

1. The first step for a contractor might be to **consolidate some of its internal functions** – such as procurement, quality and logistics – into a central team, to work more closely with the supply chain.

2. The contractor would then abandon the old system – multiple, ever-changing transactional supply contracts, with great complexity and little reliability for both sides – and switch to a new system involving fewer contracts but more strategic long-term cooperation.

3. Such a switch not only **will reduce the contractor's administrative burden and initial set-up costs**, but will enable suppliers to conduct long-term planning, and will often bring innovations to the market. Nevertheless, the long-term commitment should be accompanied by a transparent, fair and regularly revised evaluation of the suppliers.

EXAMPLE: The UK-based contractor Prater recently won a supply-chain-integration award for its long-term commitment to its suppliers; the company hosts an annual supply-chain conference, for example, where common strategies are developed.

Enhanced Management of Subcontractors and Suppliers

EXAMPLE: The US-based homebuilder David Weekley Homes conducts a quarterly evaluation of its suppliers' performance in areas such as reliability, communication and timeliness, and honors "partners of choice" with annual awards.

- ✓ Finally, the increased adoption of digital technologies like BIM can also help to integrate the supply chain more closely. It could improve service levels and reduce costs, particularly by connecting disparate systems and by providing end-to-end visibility into the supply chain.

EXAMPLE: SAP solutions for Connected Construction aim to connect all construction equipment onto a single platform and to ensure just-in-time delivery of supplies. The process involves analysing real-time operational data, monitoring exceptions, forecasting changes and adapting to them dynamically as they occur on construction sites.

- ✓ Following Toyota's innovative use of "lean" methods to **improve productivity** in automotive manufacturing, manycompanies in discrete and process manufacturing industries have applied "lean" to manage complexity and drive step change improvements in efficiency. For project businesses like construction, it is **more difficult to apply "lean"**, given the great complexity of their operations (one-off projects, varying teams, and so on) and the challenge of external factors such as the weather.

- ✓ That said, those construction companies that have successfully applied lean methods have **reduced construction time by up to 30%** and **reduced costs by up to 15%.** But the adoption of lean methods is still not widely prevalent in the construction industry, despite the relatively low investment needed. To make major and lasting productivity improvements, the industry must embrace lean construction more broadly.

- ✓ A lean approach **reduces complexity and uncertainty by reducing waste and non-value-adding activities** throughout the entire value chain: it reduces, for instance, schedule deviations, waiting, stocks of building materials, transportation, rework and unused or underutilized resources. In that way, it makes processes more stable, predictable and efficient.

Four core principles underlie the use of lean methods in construction projects (see Figure 12):

1. Alignment of resources, material and information flows. Optimize the construction process by, for instance, identifying repeatable elements and sequencing the various work shifts accordingly. For example, the building could be divided into several sections to allow a value-creation flow based on the orchestrated movement of subcontractors and craftspeople through each section.

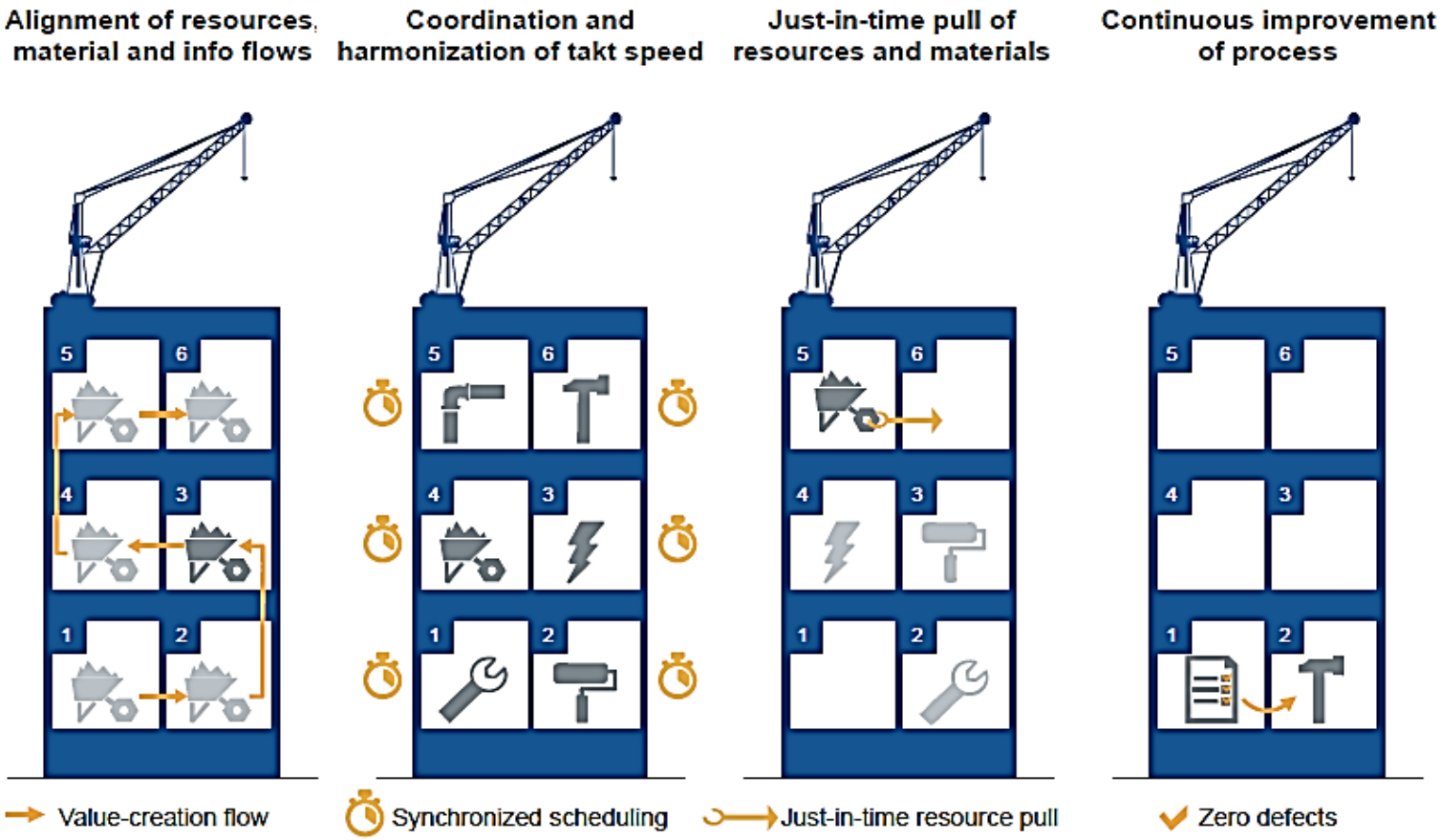
2. Coordination and harmonization of takt speed.(Takt speed is, roughly, the work pace or rhythm; typically, work cycles vary from one day to one week.) Synchronize the steps, identify and ease bottlenecks, and smooth the flow of construction work to avoid idle times by, for instance, sizing teams appropriately and moving rework to night shifts or weekends.

3. Just-in-time pull of resources and materials. Plan work at the "request" of a downstream "customer". Ensure that the availability of materials is in sync with the progress of construction by, for instance, transporting materials "just in time" and to precise locations on the site. This approach also promotes flexibility, by allowing contractors to accommodate their clients' last-minute decisions.

4. Continuous improvement of processes. To minimize delays and defects, **implement continuous monitoring** and **make use of regular feedback loops** via, for instance, **daily and weekly meetings and project steering routines.**

EXAMPLE: Despite an initial six-month delay on a plant project in Brazil (due to the need for soil improvements), BMW nevertheless completed the construction extremely efficiently: it managed to halve the expected construction costs and build 50% faster than scheduled. This success was largely due to the rigorous adoption of lean construction methods. Prefabrication, for example, enabled takt planning for iterated quadrants; regular stand-up meetings, on-site dashboards and key performance indicators (KPIs) were used to create transparency and to improve the exchange of information; and integration workshops, conducted for suppliers at each project phase, improved collaboration.

Figure 12: "Lean" Principles in Construction[69]



- ✓ Lean processes bring about improvements not only in cost and delivery time but also in quality and safety.
- ✓ Safety is a crucial area of action for the construction industry, during all project phases. The industry has made great progress in the recent past, yet it remains one of the most dangerous industries to work in.
- ✓ It must continue its efforts to **reduce the hazards involved** and to **raise labor standards** in construction globally. This imperative applies to the whole supply chain, and it is particularly demanding: the fragmentation of the industry, together with a lowest-price culture, often **entails compromises on labor or environmental performance, as evident in informal employment arrangements.**
- ✓ **New digital tools** can help greatly in this crucial endeavor; for example, RFID enables automated collision prevention of workers and machinery. But it takes more than technology, of course: more rigorous approaches are also essential if safety is to improve.

  EXAMPLE: Fluor addresses the risks to workforce health and safety by launching detailed investigations into even minor incidents, such as a “near miss” when a machine almost has a collision – even if it was “only” with a fence.

Rigorous Project Monitoring (Scope, Time, Cost)

- ✓ For the construction industry, accurate and up-to-date budgeting and scheduling are particularly acute challenges. The issue for construction companies is not only the **frequent deviations from the estimated costs and schedule**; it is also the **late detection of these deviations.**
- ✓ Typical reasons would include **unexpected soil conditions and scope changes** agreed on a lower operational level that turn out to have major implications.
- ✓ This late awareness limits the companies' ability to take timely mitigation measures or to revise the contract. In many cases, the **financial and reputational consequences are severe.**
- ✓ Currently, project monitoring in the construction industry often consists of little more than post hoc documenting of the cost overruns and construction delays.
- ✓ **Project monitoring needs to become more real-time and forward-looking** than that, and to provide data that can immediately be translated into action – action that will bring projects back on course.

Rigorous Project Monitoring (Scope, Time, Cost)

The following steps are recommended for companies:

- ✓ Establish the right metrics, and monitor continuously. **Define appropriate KPIs** that create transparency on the project's progress and enable early identification of any deviation. Monitor regularly, ideally every day, the schedule adherence of each process cycle, and report it as being either "on track" or "requiring action". Leverage state-of-the-art digital tools, big data and new construction equipment in order to generate project monitoring data more efficiently.

  EXAMPLE: ImageIn Flight is using drones equipped with cameras to generate 3D footage of construction sites continuously. Sophisticated software then compares this data against architectural plans and previous images in order to measure progress and identify areas in need of action.

- ✓ Communicate early and inclusively. Make sure to clarify and visualize all relevant information regarding the construction project in order to foster communication about the schedule and plan. For example, if displayed steering boards show the status of KPIs for scheduling and quality, that should enable teams to track progress regularly and to stay informed about the common goals.

  EXAMPLE: A public shipyard achieved impressive productivity improvements by means of enhanced collaboration and accountability between different teams, using a concept called “project room”. The project room, as a central collaboration forum, hosted daily stand-up meetings, lasting just 30 minutes, where all relevant functions were represented – engineering, purchasing, production engineering and production. Each function displayed its own information panel, featuring various colour-coded KPIs, the current state of progress, and a list of ongoing actions.

- ✓ Take the appropriate remedial action. Introduce processes for translating enhanced monitoring capabilities into improved construction practices, for example by establishing a project-quality-gate cycle involving regular site controls that immediately trigger corrective measures where necessary.

  EXAMPLE: Fluor uses a system-dynamics model to simulate the impact of potential changes on a diverse range of construction projects, and thereby to improve decision-making and client information. By seeing the cause-effect paths, planners can more easily establish what remedial actions would be most effective in reducing the impacts.

Rigorous Project Monitoring (Scope, Time, Cost)

BIM can play an essential part here: it comprises the graphical model of the asset, information on construction sequences over time and information on costs, and thereby allows for continuous monitoring.

Another important topic is the need to capture "as-built" information from projects, in contrast to "as designed", which is what the original design drawings contain. This is of paramount importance: unless it is possible to know how the asset has been built on the ground, accurate life-cycle performance models cannot be developed and life-cycle costs cannot be optimized via the intelligent planning of future maintenance and rehabilitation actions. Especially with the help of modern equipment and technology, the necessary information can be captured and "as-built" records developed. That will help not only with **optimizing the life-cycle costs**, but also in confirming that an asset has been constructed as originally intended and thus in **protecting clients from fraudulent contractors.**

EXAMPLE: Atkins has worked with several clients worldwide, including Heathrow Airport, to advance the leverage of laser scanning technologies to automate 3D/BIM model creation and support a basis for asset tagging and management to optimize O&M.

Differentiated Business Model and Targeted Consolidation and Partnerships

Competition in the construction market is traditionally fierce, and margins are accordingly slim. Many construction services are highly commoditized, and tender procedures exacerbate the cost pressure. Many firms are therefore seeking opportunities to differentiate their services in the marketplace and identify their "sweet spot" strategic focus. They need to define their sector coverage – finding the right balance between specializing in a specific industry and developing customized solutions on the one hand, and becoming more general and thereby achieving economies of scale and diversifying risk on the other. And they also need to decide on their value-chain coverage – that is, their scope of services from design and engineering to construction to O&M.

EXAMPLE: Fluor, in response to the need for great capital efficiency from clients, has focused on being an integrated engineering, procurement, fabrication and construction company. It also plans to integrate further services, such as operations, maintenance and water treatment. It has invested in additional fabrication capacity, allowing for modular execution with pre-assembling, and – in keeping with its aim of strengthening its integrated-solutions capabilities – it recently announced the acquisition of Stork, a global provider of maintenance, modification and asset integrity services.

Differentiated Business Model and Targeted Consolidation and Partnerships

Liaisons with start-ups or other firms with a digital background can also help large established companies to absorb digital advances quickly and effectively. For instance, a US E&C giant recently partnered with the technology startup company Skycatch, which has unique expertise in the use of drones.

As the boundaries between traditional roles and companies begin to blur (thanks to BIM, for example), new disruptive business models will emerge. Consider the following two examples, which are trying to redefine ways of construction:

> EXAMPLE: The British insurer Legal & General will invest £50 million in a "flat pack" housing factory to prefabricate complete homes, including white goods and interiors. As part of this disruptive move, the insurance giant has teamed up with the Dutch pension-fund manager PGGM. They will construct 3,000 apartments across the United Kingdom, under a £600 million "build-to-rent" plan, to help tackle the housing crisis.

EXAMPLE: Aditazz describes its “visionary” approach to construction as being based on innovation, particularly by integrating technology, design and modular manufacturing. From architectural work via engineering to final project delivery, the company handles all aspects of building new healthcare facilities, by means of a single innovative data driven platform. That suggests a business model heavily inclined towards investments in technology, processes, people and the integration of the supply chain, and a unique selling proposition based on innovation.

Sustainable Products with Optimal Life-Cycle Value

On a typical vertical construction project, over 30 years of a building's life, the present value of O&M and utility costs is nearly as large as the initial project costs. Even so, it is still not standard in the industry to make a deliberate life-cycle-cost optimization of the final asset. Multiple possible reasons explain this neglect.

1. **Conflicting interests between developer, constructor and asset owner, owing to trade-offs between initial investments and the subsequent life-cycle costs.**

2. **The absence of a neutral and unbiased view of the life-cycle value of built assets.**

To remedy this unsatisfactory situation, the industry should invest in designs and systems with improved long-term life-cycle performance – considering not only the "first costs" of a building (design and construction expenses) but also long-term costs, such as utilities, O&M and externalities.

Several companies are conducting pilot schemes to test such new systems, collect information and generate convincing evidence of value.

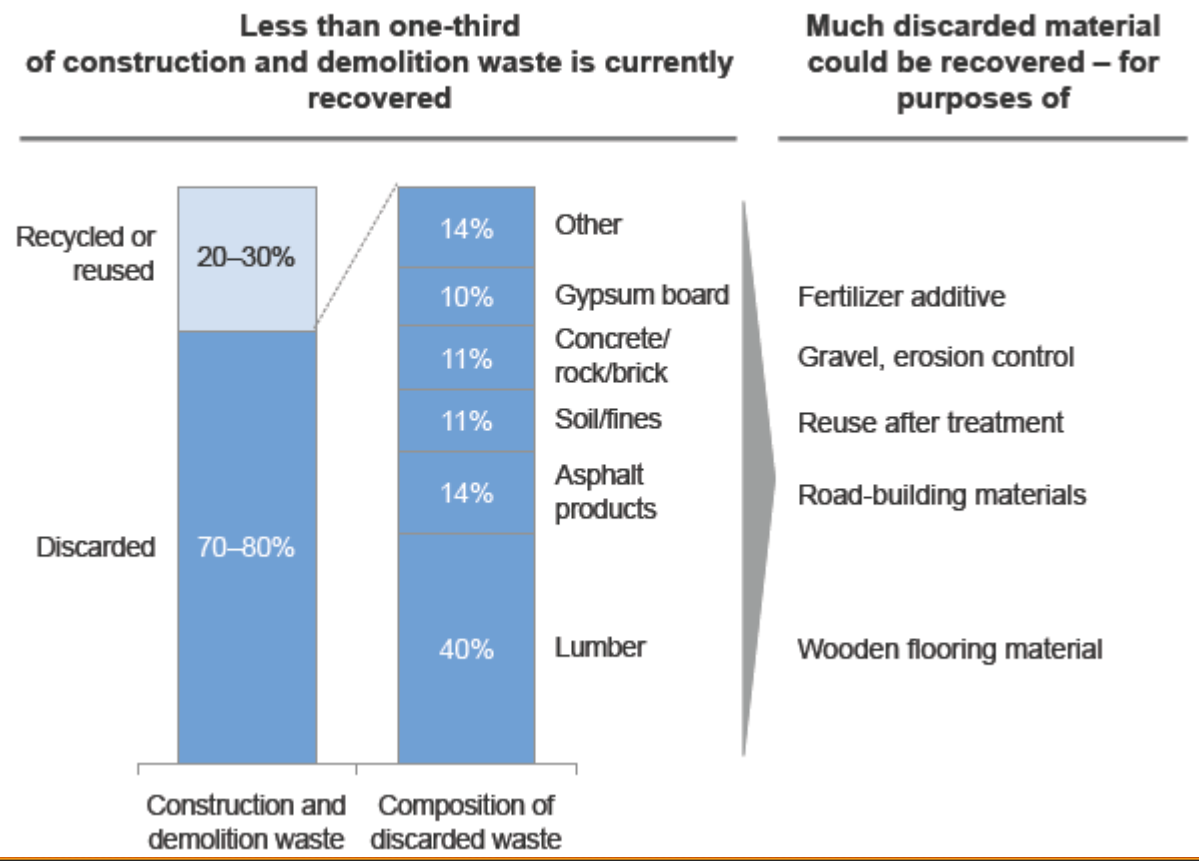
EXAMPLE: *LIXIL's U²-Home* and *IoT House* products use sensors to collect data from residents, and then use the data to derive patterns and insights related to human-centred living technologies. In addition, *LIXIL* has developed **wireless power-supply tiles** based on magnetic field resonance and is thereby improving the life-cycle performance of buildings. The construction phase benefits from the increased flexibility, now that power is available through the building materials; the operations phase benefits, in that lighting and other light home appliances can now be powered without the complication of electrical wiring.

EXAMPLE: *Bre innovation parks*, with current hubs in the United Kingdom, Brazil, China and Canada, are showcase neighborhoods that experimentally incorporate new sustainable construction technologies with increased life-cycle performance. For instance, an **insulation material**, originally developed by NASA, has been adapted for use in window blinds that control heat in different seasons, and can save up to 40% of energy costs during the operations phase.

Sustainable Products with Optimal Life-Cycle Value

In addition to developing products with optimized whole-life-cycle costs, construction companies need to follow another strategic imperative, namely, to **incorporate principles of sustainability into their strategies and business models.** Given the scarcity of natural resources and the high societal cost of construction externalities (notably, the emission of carbon dioxide, and the pollution of soil, water and air), the industry has a major opportunity here to contribute to a more sustainable world economy. Just consider the amount of construction and demolition waste that is currently not recovered in the United States (see Figure 13) and the manifold opportunities for recycling.

Figure 13: Construction and Demolition Waste: A Notable Opportunity[78]

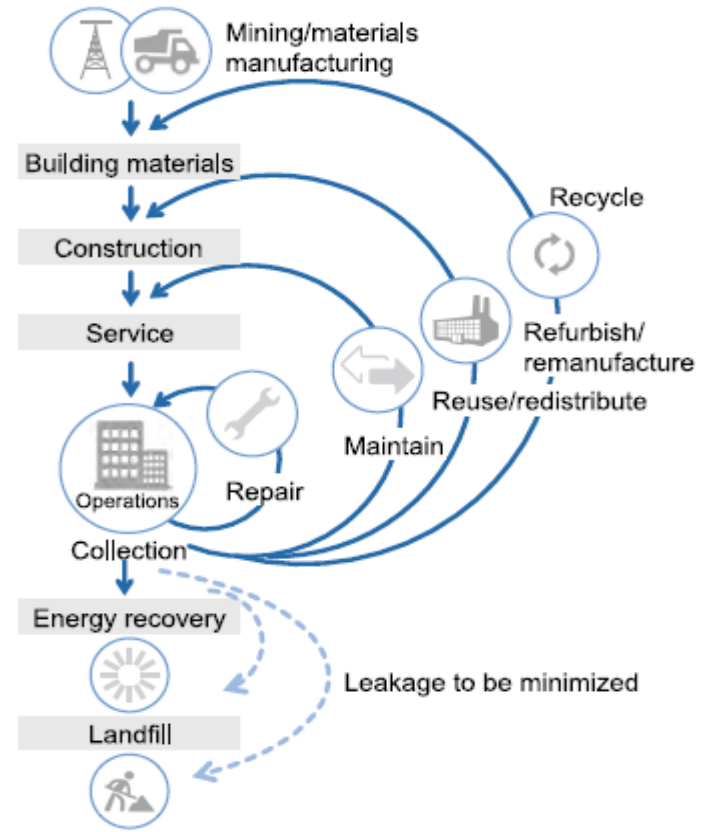


Sustainable Products with Optimal Life-Cycle Value

To make their business more sustainable, construction companies should consider closed-loop circular design principles as described in Figure 14, and embed them into their product portfolio and business models.

EXAMPLE: *Tarkett has* committed to making a transition to the circular economy and has developed an approach called *Closed-Loop Circular Design*. The foundations of this approach include choosing "good" materials that can be recycled; minimizing the environmental footprint during production (by such means as a closed water cycle, or the use of biomass to produce energy); creating products containing, for instance, minimum levels of total volatile organic compounds; and changing from an end-of-life to an end-of-use mindset for products.

Figure 14: Circular Economy Principles in the Construction Value Chain[80]



Sustainable Products with Optimal Life-Cycle Value

Another worthwhile endeavour is to develop and institutionalize new forms of planning that incorporate sustainability and whole-life-cycle concepts.

EXAMPLE: *Atkins* applied Transit Oriented Development – an approach to development that focuses on land uses around a transit station or within a transit corridor – in all development phases of the *Cadre International Center* in Guangzhou. The results included improved living, working and commuting conditions, and enhanced use of public transport. Atkins also applied a new type of urban planning, aimed at boosting sustainability from the earliest stages. In close collaboration with China's Ministry of Housing and Urban-Rural Development and other stakeholders, Atkins developed a clear, practical framework, incorporating a sequential, process-based, step-by-step agenda for sustainable urban planning.

Internationalization Strategy to Increase Scale

Construction firms have traditionally focused on their home countries, as construction is a local business in which local relationships, assets and resources are extremely important. This tendency militates against economies of scale, however, especially for very large, complex construction projects. As emerging countries accelerate their urban and industrial development, new construction markets are opening up for developed-country companies. At the same time, emerging-country companies are interested in getting involved in projects in developed countries. It is crucial for all companies in the industry to develop a clear internationalization strategy.

Many companies are already establishing a foothold in foreign countries and striving to boost their market share there. When entering new countries, companies will usually find that the best strategy is to cooperate with local firms, via strategic equity alliances and joint ventures, or else to pursue mergers and acquisitions. In that way, they can combine their own expertise with the incumbent partner's local knowledge and relationships. In many fast-growing markets, the local authorities actually advise, request or even require such partnerships.

The value of local partners is particularly high in respect of understanding national or regional regulatory requirements, dealing with the local labour force, and negotiating a way through cultural or bureaucratic obstacles. Choosing a local partner is seldom easy, however, as knowledge of the candidates is limited.

Internationalization Strategy to Increase Scale

EXAMPLE: Through acquiring *Foster Wheeler* in 2014, *AMEC* increased its presence in the Latin American market, gained additional expertise in the oil and gas segment, and doubled revenues from developing markets. In 2015, the newly merged company formed a joint venture with the Ghanaian company *BBS Engineering* to combine the incumbent's local skills, knowledge and experience with its own international standards and global capability and quality.

EXAMPLE: *Atkins* recently announced the acquisition of *Howard Humphrey*, based in Kenya and Tanzania, thereby expanding its global infrastructure presence into East Africa. Atkins is leveraging Howard Humphrey's engineering consultancy and project management services in the transportation, water and property markets.

Strategic Workforce Planning, Smart Hiring, Enhanced Retention

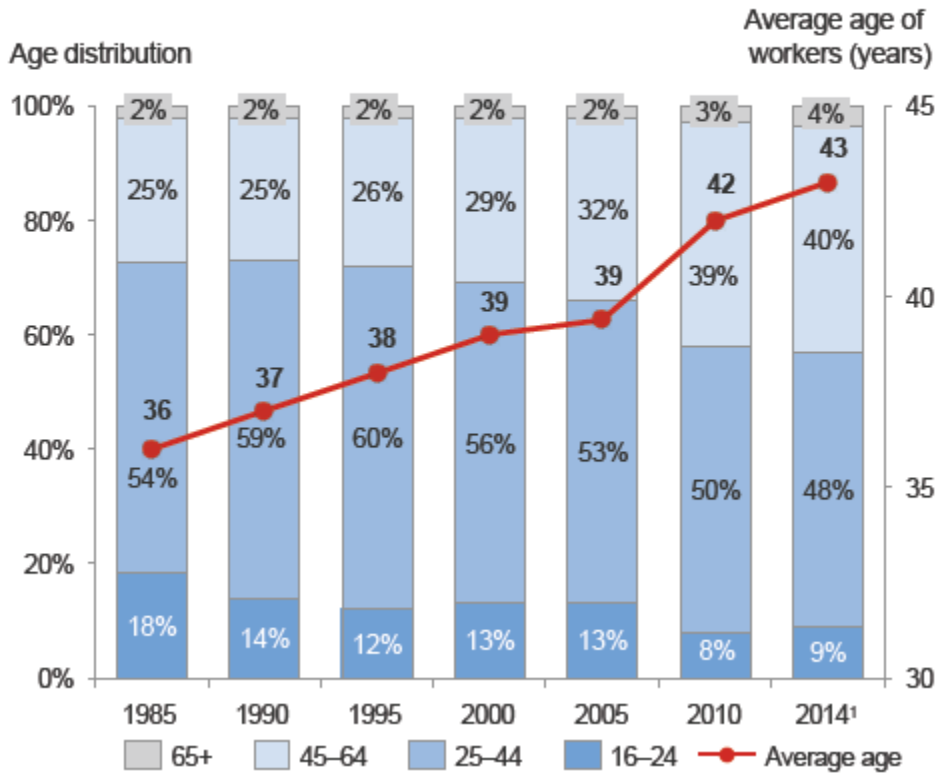
The E&C industry will face stiff recruiting and talent challenges in the years ahead. One major challenge is the prospective scarcity of skilled labour, driven by demographic shifts in developed countries.

A case in point is the United States: between 1985 and 2014, the average age of construction workers surged from 36 to 43 years, while over the same period the proportion of soon-to-be retirees (aged 45 to 64 years) increased from 25% to 40% (see Figure 15).

Another serious challenge relates to the increasing sophistication of technology, which demands new and broader skill sets at all levels of a company.

A final challenge is the high volatility of workforce demand and composition: staff demands become evident at short notice following a competitive tendering bid, and the execution of contracts typically requires the short-term integration of a transient workforce from multiple subcontractors.

Figure 15: Worker Age in the US Construction Sector, 1985-2014[82]



"Our business is really all about people. You can have equipment and financial resources, but to truly succeed in a business like ours you need to have the right people in the right places."

Peter Bjork, Vice-President, Information Systems Strategies, Skanska, Sweden

In response to these challenges, construction managers need to engage in *strategic workforce planning*, in order to anticipate their company's workforce needs and priorities well in advance. In addition, they need to develop pre-emptive measures, such as comprehensive talent management, including *smart hiring* and *enhanced retention* strategies.

Strategic workforce planning. This planning involves a scenario-based approach that will keep a business sustainable from a people perspective. The steps are as follows:

1. *Take a long-term view of workforce demand*, by simulating the future project pipeline. This forecast should be made on a granular skill-cluster level: it should consider, for example, **future skills requirements in the digital space or the need for local market experts**, but also expected productivity gains through technological advances. Note that changes can go both ways: there will be a need to upgrade relevant (digital) skills and provide the appropriate training; on the other hand, some complex tasks will now be performable by lower-skilled workers, thanks to decentralized information and perhaps augmented reality.

2. *Simulate the workforce supply accordingly* based on existing staff rosters; consider, for example, shifts in age profiles and capacity losses through attrition.

3. *Identify gaps and risks,* and devise, on that basis, an executable workforce plan, including interventions to address any over- or under-supply of staff and any skills gaps. Initiate measures, such as recruiting, training, transfers, in-/outsourcing or lay-offs, appropriate to the significance for the business and to the time for qualification. For instance, in more developed markets, the construction sector could provide good entry-level jobs for refugees, whose upskilling potential is great, and who could rejuvenate the current workforce.

EXAMPLE: *Fluor* maintains a database of information on high-performing employees – their experiences, training, mentoring and career goals – and matches it with the expected demand over the next decade in each of the 30 countries where it operates. In this way, the company can align global talent-development efforts with its long-term strategic plans.

Strategic Workforce Planning, Smart Hiring, Enhanced Retention

4. Smart hiring. In a 2014 survey of more than 1,000 construction firms in the United Kingdom, 36% of the firms that had tried to recruit skilled staff reported difficulties in filling the positions. This recruiting problem spans all occupational groups – from skilled workers at the construction site to functional specialists at headquarters. In an industry with a traditionally poor employer image on the labour market, smart hiring practices can be a powerful tool to attract the requisite talent. Besides investing into a strong recruiting brand, managers of E&C firms and suppliers should consider taking the following steps:

- Establish customized recruiting channels for key target groups; set up a social-media-focused recruiting team; build up capabilities to address unfamiliar candidate pools (such as IT specialists).
- Increase efforts to achieve gender equality in construction; that involves not only making changes to attract more women, but also recognizing and building on the strengths and characteristics of women.
- Promote the role of technology and the broader societal impacts of construction, especially when pitching jobs to younger people.
- Engage in partnerships that create a pipeline of suitable candidates (for example, university collaborations).

Strategic Workforce Planning, Smart Hiring, Enhanced Retention

5. Enhanced retention. Ultimately, the success of any human resources strategy depends critically on the company's ability to create a "preferred employer" position and thereby to retain the requisite diversity of skills and the right number of top project managers. According to the US Bureau of Labor Statistics, the E&C industry records some of the highest employee turnover rates across all industries – in 2014, a remarkable 21.6% of construction workers quit or had to quit their job. This churn is particularly troublesome in long-term large-scale projects. In the United States alone, unwanted employment turnover is creating additional costs for E&C companies estimated at $140 billion annually, in recruiting, training and administration. For E&C companies to mitigate attrition, the following measures are crucial:

- Provide attractive benefits, both intangible (such as training and recognition) and tangible (notably, adequate compensation packages and retention-incentive programmes).
- Tailor messages and career-development offerings to target groups (women, for instance, or millennials).
- Cater for the specific needs of older workers (including workers with reduced physical capacity) – for example, by pairing them with junior workers in blended crews.
- Consider all psychological aspects (corporate social responsibility, executives as role models, and so on).

EXAMPLE: For several years in a row, *DPR Construction* has been ranked among Fortune's "100 Best Companies to Work For". Notable elements of the company's human resources strategy are a strong mission statement ("we exist to build great things") and progressive values (integrity, enjoyment, uniqueness and ever forward); title-less business cards to allow individuals to take on multiple roles and levels of responsibility; an open-office environment, including wine bars; and free use of company-owned vacation property.

Continuous training of staff can help to address the various challenges confronting the E&C industry – the demographic changes, the technological and process advances, and the legislative and regulatory requirements. For instance, project managers will eventually manage multi-billion dollar projects – and the required skills need to be developed accordingly, starting in the early stages of a career. In addition, the provision of training can make employees feel more appreciated and can contribute to a more vibrant company culture. Relative to other industries, construction companies conduct few people-development initiatives. In the United Kingdom, for example, only 57% of construction firms funded or arranged training for their staff in 2015; just one sector fell below that figure – the agriculture sector, with 50%.

Continuous Training and Knowledge Management

Effectively designed training systems should improve both the performance and the engagement of workers, and also their health and safety. The best practices include the following:

- *Align training efforts to business strategy.* Design or adapt training programmes and curricula to prepare employees for the organization's current and future needs. **Occupational safety and health (OSH) training** should be a key element. Break down functional silos by, for instance, complementing technological know-how with commercial capabilities, or broadening the skill set through job rotation along the value chain. Pay adequate attention to soft skills (notably, leadership or cultural interests) and hard content (such as lean construction or project management). One of the top priorities of many E&C companies over the next few years will be the upgrading of digital skills.

- *Offer rich development opportunities.* Effective training combines multiple approaches: in-house and external (for example, through partnerships with education providers, corporate universities or key suppliers, such as chemicals or equipment firms), as well as formal (classroom courses) and informal (coaching and mentoring, on-the-job) to ensure that knowledge is efficiently transferred to the younger generation. Exploit technology, by adopting e-learning, simulation-based training and automated tracking of learning progress.

- Include all staff. Customize offerings to different target groups (for instance, construction workers, functional experts, senior management), taking into account the different needs of diverse generations within the workforce (traditionalists, baby boomers, generation X, millennials).

  EXAMPLE: *Fluor* recently gave $1 million to the University of Houston to establish a partnership in construction-management education, focusing on research and professional development.

  EXAMPLE: *Skanska* has implemented an organization-wide, cloud-based training system to continuously track capability development along the employee life cycle. For example, as employees take classes, the supervisors can consult the system to monitor progress and align the content to each individual's development plan.

So, people development ensures that staff continuously grow and acquire the right skill set. It does so by leveraging the company's knowledge base. But what happens to the extra knowledge or intellectual capital that is being created every day on projects or in internal R&D? That too needs to be actively managed and exploited. *Knowledge management* should be given a key role on any corporate agenda, yet many construction firms make poor use of such a rich resource. Accordingly, they **fail to benefit from experience as they move from one project to another,** working with different partners along the value chain. E&C companies need to take action in three main areas, as follows:

- *Take a structured, coherent approach to knowledge management.* Implement appropriate processes and functions, so that the **capture, consolidation, dissemination and reuse of (project) knowledge** become everyday activities. By institutionalizing things in this way, companies enable their employees to access and apply the right knowledge, at the right time and in the right place.

  EXAMPLE: *Fluor*'s Vice-President of Innovation brings innovations into the organization by acting as a cauldron of ideas, evaluating new methods qualitatively and quantitatively; Fluor's Vice-President of Continuous Performance Improvement makes sure that tools and techniques are continuously updated and improved.

- *Foster a culture of proactive knowledge sharing.* In the E&C sector, many **experienced professionals view knowledge as power and are reluctant to share it.** What's more, the workforce often seems unwilling to learn from others' experiences. To overcome these cultural barriers, companies need to **clearly articulate objectives and guiding principles for knowledge sharing – and provide appropriate incentives.**

- *Create transparency on the internal skills available.* Given the enormous variety of construction projects and the difficulty of instantly finding individuals with the relevant expertise or project experience, E&C companies should **maintain centrally an accurate employee database.** Only in this way will they be able to optimize their workforce allocation. The database should include at least the **work record** and **project experience** of each employee, and thereby facilitate the informal exchange of knowledge.

Leverage technology. Information technology has long been recognized as a critical facilitator of successful knowledge management. Among the most common and useful tools are **groupware systems, intranets and extranets, and content management systems.** For E&C companies in particular, BIM has the potential to greatly facilitate the management of project knowledge – for instance, by integrating comprehensive object libraries and by **enabling real-time, on-site access to supplementary information.** Companies can also derive great value from augmented reality, as a means of **providing visual instructions to workers on-site,** particularly those engaged in O&M work.

EXAMPLE: *Arup's* approach to knowledge management is regarded as one of the most advanced in the E&C industry. The company's resources include:

1. a system for capturing lessons learned on projects and for accessing key project data
2. a comprehensive BIM library with more than 25,000 objects
3. virtual communities that globally link employees who work on different projects but face similar problems
4. various facilitation techniques to encourage knowledge sharing (for example, Arup university lectures, workshops and story-telling events)

High-performance Organization, Culture and Incentive Schemes

Many construction firms are still characterized by a rather conservative company culture and mindset, and are often **hampered by organizational inertia.** To support their overall business goals, companies need to drive **organizational change** – an iterative process, which requires careful alignment of company culture and goals, organizational design and incentive schemes. In particular, it involves the following steps:

- *Conduct an organizational "health-check" and refine the company's purpose and culture.* Evaluate the degree to which **company culture and the working environment are conducive** to individual and team performance, innovation and improvement, collaboration and knowledge sharing, ethical principles (for instance, related to safety, the environment or transparency), diversity and inclusion, and openness and trust. Create a (revised) mission statement and statement of values, as well as a detailed plan for achieving new goals.

  EXAMPLE: *Skanska* crystallizes its company purpose in the motto "We build for a better society" and its core values in the injunction "Care for life, act ethically and transparently, be better – together, and commit to customers". These credos underline the company's focus on ethics, responsibility and sustainability.

- *Establish a supportive organizational design.* Construction is a local-project business that requires decentralized operative decision-making, close to the client. In such a context, it is perhaps more difficult, though no less important, to create an effective organizational design that reinforces a common company culture and supports strategic objectives. In optimizing the organizational design, E&C managers should consider taking the following measures:

  i. Align the organizational design with individual capabilities and roles, accountabilities and collaboration

  ii. Define appropriate structures and operating models for corporate, support and project functions; choose the appropriate structure (notably sector, regional or matrix perspectives), carefully aligned with strategic goals; define clearly the role of the centre, and pursue the solution that is best for the company rather than for the project (for instance, apply frame contacts more rigorously)

iii. Streamline the organization (by de-layering, for instance) and **optimize work dynamics** (for example, by applying lean principles); develop **hybrid organizational solutions** offering the best of both worlds (centralized vs decentralized) and finding a compromise between **scale and efficiency,** while maintaining a **business focus** (for instance, a centralized organization for megaprojects, such as nuclear power stations, requiring global expertise vs a decentralized organization for municipally-driven local projects, such as water supplies)

iv. **Break down silos:** reduce cultural differences between different parts of the organization, and ensure that staff of newly acquired companies are properly integrated

- *Incentivize desired behaviours.* Establish incentive schemes and related measures to reinforce engagement and affiliation and to drive behavioural change:

  i. **Motivate value-maximizing behaviour**, aligned with business objectives (for example, reward over-fulfilment – instead of bare fulfilment – of time/ budget targets); make sure that individual, project-based performance goals are in line with overall company aims; establish an effective accountability system; build self-esteem, morale and a sense of belonging
  ii. **Implement recognition programmes** that publicly acknowledge and reward employees for innovation, desired behaviours (such as knowledge sharing), or outstanding achievements (for instance, a "Work Crew of the Year" award, decided by peers)
  iii. **Offer management-development programmes** that focus on culture, as well as targeted mentorship programmes to transmit desirable values

  EXAMPLE: To engage employees in improvement and innovation, *Skanska* has implemented several initiatives, including a consultation forum for front-line workers, a dialogue week on safety issues and a **mobile app for submitting ideas for improvement.**

Mutual Consent on Standards across the Industry

Standards are desirable for different reasons. Adherence to standards helps to ensure that **products are safe, interoperable and good for the environment.** Harmonizing technical specifications of products and services can make industries more efficient, and can break down barriers to trade. For instance, the Transatlantic Trade and Investment Partnership, a proposed trade agreement between the European Union (EU) and the United States, aims at promoting trade and multilateral economic growth by harmonizing differing standards and regulations.

The construction industry **lacks robust global arrangements on standards.** As a result, it has forfeited the productivity gains that a proper modernization of the industry would have brought. And it could in future forfeit the potential inherent in digital technologies**: if it remains such a fragmented industry, unable to agree on internal standards, it is hardly likely to have much influence in determining cross-industry standards.**

Mutual Consent on Standards across the Industry

The E&C sector as a whole should take concerted action, along the following lines:

- *Affiliate and organize.* For E&C companies it already means a great deal to establish standards within their companies when working on different projects with a single client, and even more when working on different projects across different clients or even industries. E&C companies should strive to **form organizations, representing all stakeholders along the value chain, at a national, international or even global level.** They should also make sure that **relevant experts** (from academia, for instance) are represented, and that the organizations are large enough and varied enough to **truly represent the interests of the sector as a whole.**

- *Identify key standardization topics and develop a common stance.* Given the huge potential for improving collaboration among the different stakeholders in construction projects, it is vital that companies act in concert, and that all the stakeholders are on board and speak with one voice. The industry as a whole should define key areas to work on and should agree on a common perspective:
    i. Standards in software systems, interfaces and communication protocols will facilitate the digitalization of the industry as a whole: in particular, companies should establish standards in machine code for robots and automated construction equipment, and in interfaces between different systems such as BIM and Geographic Information Systems.

Mutual Consent on Standards across the Industry

ii. Standard interfaces between prefabricated modules and components will enhance system compatibility, provide economies of scale for suppliers, act as a powerful productivity driver and thus accelerate the industrialization of the sector.
iii. The standardized definition of costs, classifications and measurements along the whole life cycle will lead to greater comparability and compatibility among projects.
iv. Standards in legal arrangements, such as alliances and IPD contracts, will reduce initial costs and pre-empt legal complications for individual companies.

EXAMPLE: The *DGNB*90 (*German Sustainable Building Council*), an organization concentrating on sustainable construction, with members along the value chain, has developed certification schemes that provide a uniform basis for evaluating the planning, construction and operations of sustainable buildings.

EXAMPLE: *Australia* is pioneering the standardization of project alliance agreements to reduce the initial costs involved in establishing these agreements.

Mutual Consent on Standards across the Industry

- *Shape the agenda.* To define and set standards across different industries is a complex, multidimensional endeavour, involving multiple and sometimes competing interests. Standard-setting organizations are established for industries or specific topics, nationally, regionally or globally. The E&C sector has to make sure that it is represented in the relevant industry bodies and consortia, and can make its voice heard and drive the agenda.

  EXAMPLE: *Atkins* is providing a convenor for an ISO Steering Group (with members from private construction companies, government and academia) advising on industry standards for information management, specifically on the use of BIM during the construction phase of projects.

In many cases, **industry standards are referred to in regulatory frameworks,** either directly or indirectly, and they are sometimes incorporated into national building codes. For this reason, the industry must strive to set optimal standards ahead of regulation, so that it can shape the public agenda.

More Data Exchange, Benchmarking and Best Practice Sharing

In the past, proprietary knowledge was the key differentiator of companies in many industries. Now, the pressure is increasingly on companies to **join forces with other companies to create new products and services in an increasingly complex world.** That applies especially to fragmented industries such as E&C, with so many facets and challenges. But it is not so easy to put this imperative into practice.

To promote partnerships or even informal sharing among individual companies, a large-scale, even global, effort is needed. **Increased knowledge sharing among peers** can help to close the gap between technological development and application. For this purpose, the industry should establish a platform – perhaps a formal association – comprising top E&C firms across all regions. That platform, from its neutral and respected position, could encourage the regular sharing of best practices, benchmarking across peers, and could optimize data by ensuring its availability, comparability and protection. If offered the right incentives, companies will readily share knowledge and advice.

EXAMPLE: The *Construction Industry Institute* in the United States **collects best-practice insights and makes them available to its members;** topics range from partnering models to project planning and constructability.

3. The Industry As a Whole Needs to Drive Transformation

3.1 Industry Collaboration

More Data Exchange, Benchmarking and Best Practice Sharing

The benefits of many technological advances, such as BIM, will materialize only if the whole ecosystem is ready, but investments have to be made on an individual company level, of course. As a consequence, **first movers are at risk,** yet if nobody dares to move, the industry as a whole will be the loser. To break this vicious circle and avoid stagnation, the industry needs to agree on common targets. A joint effort based on shared commitments – on deploying new technologies, for instance – could help to reduce the risk for individual companies and provide an opportunity for an industry-wide boost.

Bear in mind that all forms of collaboration between companies have to take appropriate **precautions against violating antitrust or competition legislation.** It is the companies' responsibility to ensure that the government authorities or the courts **do not interpret "cooperation" as "conspiracy".**

3. The Industry As a Whole Needs to Drive Transformation

3.1 Industry Collaboration

Cross-Industry Collaboration along the Value Chain

Better collaboration is needed not just between peer companies but also between companies of different types along the value chain. **The current tendency is to push risk down the value chain instead of pulling innovations out of it.** A good way to encourage cross-Industry Collaboration among companies along the value chain is through industry-wide initiatives, such as joint R&D efforts and data-generation projects. Platforms could be established to facilitate knowledge exchange across the value chain, and to align perspectives on design, construction and operations. And measures should be introduced to enable independent certification and quality assurance, and thereby accelerate the adoption of new technologies.

> ***EXAMPLE:*** In late 2014, the *German Association for the Construction Industry* established the initiative "Planen und Bauen 4.0", involving various industry associations, such as those of architects, machinery suppliers and real estate. The aim was to create a national centre of competence and a communication partner for research, advice on regulation and market implementation. The initiative, with its multistakeholder cross-industry approach, should take a trailblazing role in the implementation of BIM and other digital innovations in the German construction industry.

Cross-Industry Collaboration along the Value Chain

More specifically, great benefit can be had from **creating permanent industry-wide bodies or institutions** involving all participants along the value chain. Such entities would **stimulate collaboration and foster horizontal and vertical linkages,** and would establish common rules and frameworks in an unbiased way. They could also incorporate trade associations (which currently tend to focus on transactional issues within their own technical specialist silos), interest groups, academics, and local associations and trades.

EXAMPLE: *Desso* (a *Tarkett* company) works closely with one of its yarn suppliers, which turns recovered post-consumer carpet fibres into new yarn. The two companies have shared their experiences within the *Circular Economy 100 network* – an innovation programme bringing together companies, governments, cities and academic institutions – in an effort to inspire circular-economy thinking among other companies.

EXAMPLE: The *Canadian Construction Association*, the national voice for the construction industry in Canada, represents more than 20,000 member firms in an integrated structure of about 70 local and provincial associations. Its Lean Construction Institute, founded in 2015, provides a platform for all supply-chain participants – owners, designers, contractors, traders and allied services – to collaborate on the development and application of lean tools and techniques along the building life cycle.

Industry-wide Collaboration on Employer Marketing

In an industry where **women constitute just 9% of the workforce** and where employee turnover will be an **estimated 33% in the next 10 years** – both values at the extreme, relative to other industries – a joint marketing effort by employers is seriously needed. The objectives are to **persuade young people to pursue a career in construction,** to challenge preconceptions about working in construction and to **demonstrate the variety of career options and entry routes.**

Ideally, formal centralized organizations would be set up, to pool the respective competencies of construction companies and align marketing efforts across the industry. The organizations would get all member companies to adopt a uniform stance and become involved in creating a consistent image of the construction industry. An active and wide-ranging communication effort would convey that consistent image to target groups, via marketing campaigns using multiple channels.

EXAMPLE: The *Construction Industry Training Board*, a centralized organization representing the interests of the construction industry in the United Kingdom, initiated a comprehensive marketing campaign called *goconstruct.org*. The website provides details on qualification requirements, job opportunities and salaries; a video provides several job profiles and information; and **a full advertising campaign disseminates information on the sides of buses, on billboards and in phone booths.**

Coordinated Communication with Civil Society

The E&C sector will also need to engage constructively with the public at large. Thus individual companies should adopt best practices regarding construction sites, should protect communities and the environment and should secure everyone's safety.

> ***EXAMPLE:*** The *Considerate Constructors Scheme* – a non-profit organization founded by the United Kingdom construction industry to improve its image – addresses concerns relating to the general public, the workforce and the environment. It has established a *Code of Considerate Practice* to guide the behaviour of its members.

The main influence on people's perception of the industry, however, is their personal experience of construction projects or assets. By involving the affected communities throughout the asset's life cycle – from planning and construction through to operating the asset – companies can sustainably enhance the image and reduce the likelihood of political intervention, particularly in infrastructure projects. In most cases, infrastructure projects are extremely beneficial for the wider society, and all stakeholders have a common interest in seeing this message communicated effectively.

Coordinated Communication with Civil Society

Infrastructure projects can provoke public disapproval in various ways. Many projects have a very disruptive impact on the local community despite their acknowledged advantages for wider society. And the **public tend to object when projects exceed their budgets or schedules,** especially **when national debt rates and austerity measures are on the increase.**

So companies would be well advised to engage the community early on, and continue that engagement throughout. During the planning process, for example, they should arrange formal consultations with the community as part of their environmental-impact and social-impact assessments. Such consultations will help to ease local anxieties, and also to fine-tune the design of the project and reduce inconvenience during the construction period: well-planned route management, for instance, will make diverted traffic more bearable for local residents. In general, companies need to maintain a strong communications strategy. During the planning period, and throughout the construction phase, project developers should keep the local community fully informed on progress and potential impacts – to satisfy curiosity, allay fears and even rally public support for the project.

EXAMPLE: The redevelopment of *Vienna's main station* was supported by the "Infobox", Europe's highest wooden tower. It became a magnet for visitors, and hence a fertile venue for circulating details of the project's goals, progress and long-term advantages.

Effective Interaction with the Public Sector

Companies should also take steps to engage constructively with the public sector to avoid misunderstandings, discuss the impact of regulations and ensure good relations. Figure 16 outlines one approach to regulatory engagement.

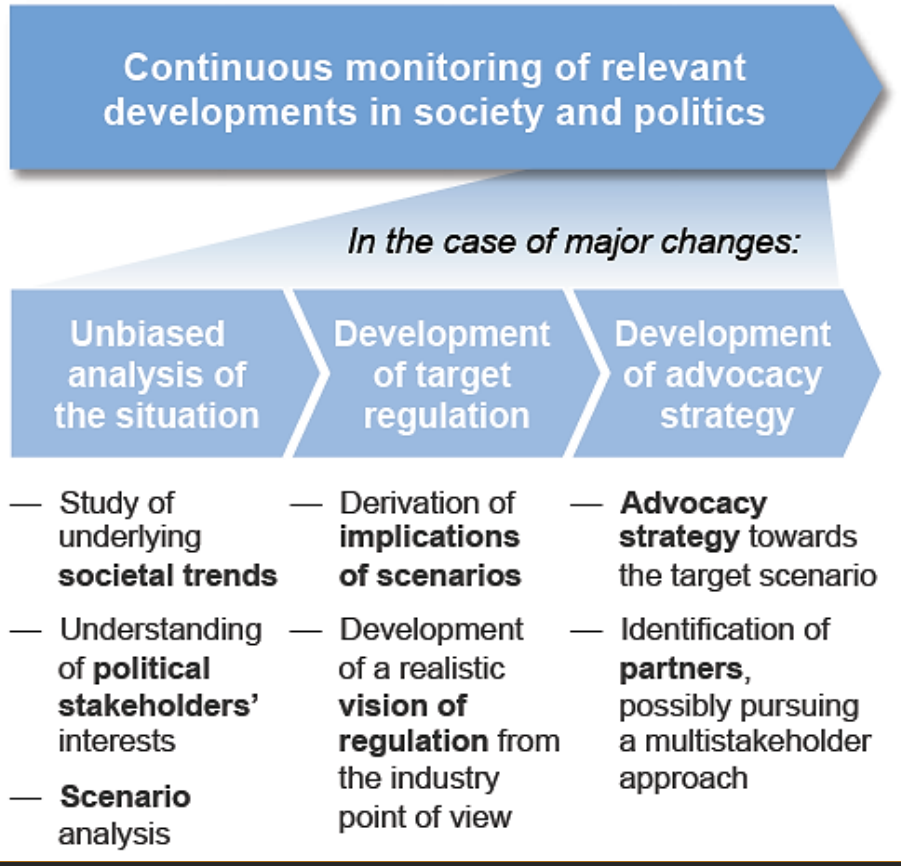
The advocacy strategy is especially important as a counterweight to the regulatory regime, which is always subject to change at a national or even international level. Ideally, the industry would engage in joint initiatives with government, working closely together towards the common goal of taking the industry forward.

> ***EXAMPLE:*** *Construction 2025* is a partnership in the United Kingdom between E&C and government to transform the industry by optimizing the relationship between private companies and public authorities. E&C is acknowledged as an "enabling sector having a massive impact on the performance of the wider economy". It has set out a vision and a plan for long-term strategic action by government and industry: they are to continue working together, especially on smart technologies, green construction and overseas trade.

Coordinated Communication with Civil Society

Engagement with the community should not end when the construction phase ends. Ongoing public support for the infrastructure asset is crucial, and cannot be taken for granted. During the operations phase, various public relations and educational measures are possible, such as **guided tours** in ports and viewing decks in airports.

Figure 16: An Approach to Regulatory Engagement[94]



Effective Interaction with the Public Sector

Once again, effective communication between the two sides is crucial. The industry needs a well-designed communication initiative for each phase in the life cycle of an infrastructure project. **During bidding and contract** negotiations, for example, companies should **refuse to give any misleading information,** even if such information is requested by the public-sector representatives. During the construction phase, the contracted company should be open and proactive in reporting progress or problems to the public-sector agency. And ideally, the company will employ a high-level individual as the dedicated point of contact, to build trusting relationships and resolve issues promptly.

4. Government Needs to Encourage and Support this Transformation

4.1 Regulation and Policies

Harmonized Building Codes/Standards and Efficient Permit Processes

As a regulator and policy-maker, a **national government** can influence the E&C industry in various ways. Primarily, it acts as a **warden of health, safety and environmental conditions in and around construction,** and it should perform this task as efficiently as possible to mitigate adverse effects on productivity. It also impacts on firms' strategies and operational practices by preventing or supporting competition nationally and internationally. And it can influence the speed and direction of technology development and diffusion.

Smart regulation is the key: it ensures that standards are met in an efficient and effective way. In addition, the regulatory framework should **leave room for technological progress and should anticipate emerging needs.** To achieve these objectives, it is crucial to have well-designed building codes and standards, as well as transparent and streamlined permit processes.

4. Government Needs to Encourage and Support this Transformation

4.1 Regulation and Policies

Harmonized Building Codes/Standards and Efficient Permit Processes

Regarding building codes and standards, the following best practices stand out:

- *Strive for more uniform regulations.* Multiple overlapping or highly fragmented standards can cause builders and local authorities to become confused. This results in delays, uncertainty and disputes. To reduce complexity, it is therefore crucial to harmonize building codes and standards at a national (or international) level, while at the same time taking into account **location-specific requirements concerning geography, climate and traditional building practices.** For efficient application, building codes and standards should also be easily accessible; ideally, they should be freely available online and through electronic devices.
    - ***EXAMPLE:*** The *Eurocode initiative* harmonized methodologies for design and calculation for construction projects in the EU, though specific rules and detailed standards still remain at the national level.
- *Update provisions regularly.* Building codes and standards need to be adaptable and up-to-date to appropriately reflect economic, societal and technological change. This regular updating is particularly important in the light of growing environmental concerns and the emergence of new digital tools such as BIM.

- *Implement outcome-oriented standards where appropriate.* Performance-based building codes are an effective means to encourage innovation in construction techniques and materials. **The codes specify the performance standards that a building must abide by, rather than specifying the ways of achieving those standards.** The codes do involve a cost: to maintain control, it is imperative to ensure the adequacy of every single design and construction path selected. This can be an intricate task, especially if there are a great many alternatives and if their performance is difficult to measure.

  EXAMPLE: *New Zealand's building code* is exclusively performance-based. For example, it prescribes that in the event of fire, the evacuation time must allow occupants of a building to move to a place of safety without being exposed to a fractional effective dose of carbon monoxide greater than 0.3.

4. Government Needs to Encourage and Support this Transformation

4.1 Regulation and Policies

Harmonized Building Codes/Standards and Efficient Permit Processes

Construction-permit processes are a major source of project **uncertainty and delay in many countries.** A government can apply measures such as these to improve efficiency:

- *Make approvals more convenient and faster for builders.* Building plans often need to be approved by multiple different agencies. To coordinate their efforts better, and to increase the speed and convenience for permit seekers, regulators should strive to ease any bottlenecks and **reduce bureaucracy associated with processes.** For example, they could **establish "single-window" systems** and **one-stop centres** that combine the required competencies under a single roof and commit to specific timelines for approval.

- *Differentiate approvals by risk.* Different assets vary in their social, economic and environmental impact. Simple or **low-risk projects require fewer checks** and can be approved faster than more complex structures. Effective regulations therefore involve rigorous yet differentiated approval processes, which **treat buildings according to their risk level.**
  - ***EXAMPLE:*** The *European standard* defines three "Consequence Classes" based on parameters such as size, construction method and final use. Each building category lists recommended interactions with the authorities, including fast-track approval procedures for low-risk buildings.

- *Digitize construction permits.* A proficient deployment of IT not only reduces the costs of approval processes, but also enables regulators and practitioners to cope with increasingly complex building standards and additional policy objectives (such as those related to energy efficiency). Particularly promising in this context is the development of **BIM-based software tools** that are **capable of automating the verification of building-code compliance.**

  EXAMPLE: In the *United States*, advanced e-permit systems and mobile inspection technology have reduced approval times by 30% and the number of required on-site inspections by 25%.

Finally, governments should establish appropriate control mechanisms and sanctions to help enforce their statutory provisions, and thereby better protect public health, improve safety and safeguard the environment. **In many developing countries, 60-80% of buildings (generally referred to as "informal housing") continue to evade any form of building-related controls, which imposes significant risks and costs on the community.** The problem arises in developed countries, too: in the United States, the team assessing the aftermath of Hurricane Katrina concluded that a major cause of the amount and magnitude of damage to buildings along the coast was, in fact, **non-compliance with the building code.** Strict implementation can pay off financially: a task force led by the Institute for Market Transformation found that **every dollar spent on strengthening building-energy-code compliance and enforcement efforts will return six dollars in energy savings.**

Market Openness to International Firms and Small and Medium-sized Enterprises (SME)

Market openness to foreign firms stimulates trade as well as the movement of capital, technology and skills across the global E&C sector. It also increases the opportunity for economies of scale and scope, and for specialization of firms – two important sources of competitiveness.

Most countries have now removed legal bans on the operations of non-domestic companies, but there are still some other, equally effective barriers to foreign market entry that restrict international competition. Among the most prevalent impediments are tariffs and duties (such as fees for imported construction services); an **insufficient recognition of foreign professionals' qualifications**; and strict capital requirements for foreign firms (for instance, financial reserves that cannot be used during the duration of the project). All of these barriers need to gradually be eliminated by national governments; only then can the fully open, global E&C market become a reality.

> ***EXAMPLE:*** Within its Construction 2020 initiative, the *European Commission* plans to take action in three main areas to enhance international competition: a more open trade in building materials; a more straightforward recognition of the qualifications of foreign architects; and support services for EU-wide operations of small and medium-sized construction companies.

Market Openness to International Firms and Small and Medium-sized Enterprises (SME)

In addition, public procurement has traditionally **inhibited foreign companies' market entry** – particularly because governments have often tended to **favour their domestic industry when awarding contracts.** Local implementation of multinational agreements, such as the Agreement on Government Procurement within the framework of the World Trade Organization, can help to liberalize government procurement markets. Such agreements establish rules that require less discriminatory and more competitive forms of tendering among participating countries.

EXAMPLE: *Brazil* – a non-signatory to the Agreement on Government Procurement and historically a relatively closed construction market – has recently launched an infrastructure investment programme that explicitly encourages international participation. All infrastructure concessions of this programme are open to foreign firms, while airport concessions actually require the participation of foreign airport operators.

Market Openness to International Firms and Small and Medium-sized Enterprises (SME)

In addition to international market openness, regulators should **promote diversity and competition in the local construction sector** by encouraging participation from a broad variety of **small and medium-sized enterprises (SMEs).** In this regard, local authorities could take the following measures:

- Put in place a simplified licensing system for SMEs (such as the one recently introduced in Indonesia)
- Promote the formation of alliances between international, national and local construction firms
- Provide financial support for SMEs in E&C (such as partial risk cover for SME loan portfolios)
- Ensure equal treatment of SMEs in public-sector tenders, particularly by reducing the bureaucratic burden of procurement

Promotion and Funding of R&D, Technological Adoption and Education

Given the economic significance of the construction sector, R&D investments among E&C companies are surprisingly small. In fact, the 2014 EU Industrial R&D Investment Scoreboard ranks construction among the least R&D-intensive sectors, with a mere **1% of net revenues allocated to R&D.**

National governments can create a more fertile environment for **developing technological innovations** by providing appropriate support to companies and academia. In particular, they could take the following steps:

- **Establish centrally funded research institutions and joint industry-academia funds and technology centers**
- **Provide venture capital for E&C-related start-ups**
- **Offer tax incentives and establish schemes for contested R&D funding (by open competitive tendering, for instance)**

EXAMPLE: In 2015, the *US Federal Highway Administration* provided – through multiple schemes – funding of almost $500 million for hundreds of research projects related to improving the design, construction and operation of roads, tunnels and bridges.

Promoting R&D is just the first step: **technological advances realize their full potential only when they are widely adopted across the industry.** In a highly fragmented, multistakeholder industry such as E&C, it is therefore equally important to foster the diffusion of innovations, by such steps as these:

- Providing financial support for demonstration projects involving new technologies and processes
- Setting up incentive schemes for innovation deployment and capability development

EXAMPLE: *Singapore*, through its Construction Productivity and Capability Fund, partly reimburses the cost for:

i. BIM software/hardware, consultancy and training
ii. equipment and machines that improve productivity by at least 30%
iii. development projects featuring process innovations

4. Government Needs to Encourage and Support this Transformation

4.1 Regulation and Policies

Promotion and Funding of R&D, Technological Adoption and Education

Finally, project managers and the entire construction workforce need to be upskilled appropriately with regard to new technologies and processes. A government can support workforce education through the following policy measures:

- **Offer training programmes at job centres and in cooperation with companies**
- **Implement effective and leading-edge curricula in universities, technical colleges and apprenticeship schemes**
- **Enhance the attractiveness of E&C professions through image campaigns**

EXAMPLE: The EU-wide construction-sector initiative *BUILD UP Skills* provides a joint platform for national programmes and projects aimed at training and educating the current and future construction workforce on energy efficiency and renewable energy.

In addition to its role as regulator, the public sector also has an immense impact on E&C through its role as project owner. Government procurement accounts for a major share of total construction expenditures worldwide: for example, 31% in the United Kingdom, 44% in Germany and a staggering 57% in the United States.

As the E&C industry's most important client, governments need to actively manage and coordinate public-sector demand, and thereby drive industry change. It is also their duty to **prevent corruption in the system,** in order to promote efficiency in procurement and **provide equal opportunities for bidders.** The more progressive governments have started to reform procurement and are adjusting bidding requirements and processes to stimulate innovation and whole-life-cycle optimization.

4. Government Needs to Encourage and Support this Transformation

4.2 Public Procurement

Actively managed and staged project pipelines with reliable funding

Given the sheer size and complexity of the public-sector project pipeline, its active management is a challenging task, and one that is often badly neglected. Ideally, a government defines and implements a holistic strategy to optimize procurement along several dimensions – notably, the composition of the project portfolio, the governance of procurement activities and the attractiveness of the project pipeline to potential bidders.

When it comes to compiling the public-sector project portfolio, multiple objectives (conflicting to some extent) need to be aligned. For an optimal prioritization of projects, it is crucial to first develop a strategic procurement plan. Such a plan provides guidance for the required cost-benefit analyses at the project level, and helps to reconcile economic considerations and industrial, social and environmental targets. Once a project has been chosen, the procuring authorities should focus on maximizing efficiency in the acquisition of goods and services – for example, by choosing smart delivery mechanisms and by implementing rigorous evaluation and benchmarking processes both within and across departments.

Actively managed and staged project pipelines with reliable funding

A more effective governance of public procurement can be achieved through the following measures:

- Put in place clear organizational structures and operating models for planning and execution
- Assign task forces to drive high-priority projects
- Apply lean principles to public procurement – for example, by appointing process owners and specifying cycle and lead times
- Equip government teams with the appropriate skills and tools to function as an “intelligent client”

Finally, the public-sector project pipeline should be attractive to potential bidders. This attractiveness can be enhanced through such measures as these:

- Ensure visibility of the forward pipeline to help providers respond to market opportunities and ensure a stable project pipeline over time
- Provide a clearly defined bidding model and information-rich tenders
- Offer SMEs training on public procurement procedures
- Provide dedicated, continuous funding, ideally through a public fund

EXAMPLE: The *United Kingdom* recently launched several initiatives relating to the management of the public-sector project pipeline. To mention just a few:

i. Project pipelines for 19 sectors are being published online and updated every six months to create a level playing field for providers of any size.
ii. Cost benchmarking of construction projects across departments now provides a solid baseline for cost-led procurement.
iii. The Major Projects Leadership Academy, in cooperation with the Saïd Business School, has been established to enhance project-management skills and capabilities across government.

Strict Implementation of Transparency and Anti-Corruption Standards

Bribery and corruption exist in all industries but, in E&C-related procurement, **collusions between government staff and bidders are particularly common,** even in developed countries. A study prepared for the European Commission, examining 192 public procurement projects in eight EU countries, found a probability of corruption of 9-21% in the road and rail sector, 28-43% in water and waste, and 37- 53% in urban or utility construction. **Corruption drives up procurement cost substantially,** by an estimated €1.3-1.9 billion per year, in the eight countries studied.

To ensure integrity in public contracting and thereby promote efficiency and fairness towards bidders, governments need to rigorously **implement comprehensive anti-corruption and transparency frameworks.**

Strict Implementation of Transparency and Anti-Corruption Standards

These efforts should address all stakeholders along the value chain, and should include the following measures:

Create a corruption-resilient procurement environnent

- Generally, implement laws, institutions and practices for preventing corruption in line with international standards (for instance, the United Nations Convention against Corruption and the OECD Anti-Bribery Convention); join integrity pacts, such as the Partnering Against Corruption Initiative led by the World Economic Forum
- Ensure that procuring authorities and tenderers commit beforehand to anti-corruption
- Offer anti-corruption training courses and foster knowledge sharing across procurement departments to create a transparent culture aware of corruption risks
- Implement operational best practices, such as job rotation and screening of pre-employment history, to ensure the integrity of procurement departments and staff

4. Government Needs to Encourage and Support this Transformation

4.2 Public Procurement

Strict Implementation of Transparency and Anti-Corruption Standards

Implement fair and transparent procurement procedures

- Establish clear procedures so that all parties are equally aware of project dimensions, criteria for evaluation, and the timeline and stages of the procurement process
- Ensure that evaluators act independently from tenderers (by engaging probity auditors, for example)
- Enhance transparency by making all details of the procurement process and the results available to the public (via social networks and video streaming, for instance)

EXAMPLE: The *Construction Sector Transparency (CoST)* initiative is a partnership between participating countries and international stakeholders, designed to enhance the accountability of procuring bodies and construction companies for the cost and quality of public-sector construction projects through a standardized public-disclosure process. The disclosure includes comprehensive information about the project at different points in its life cycle, as well as justifications for any significant deviations from budget and schedule. A CoST pilot in Ethiopia, for example, showed that public-sector projects exceeded their cost targets by more than 50% and their time targets by more than 100%. As a result, departments have now committed to ensuring greater compliance with procurement regulations and to performing feasibility studies for any major project.

Strict Implementation of Transparency and Anti-Corruption Standards

Establish clear practices regarding the prosecution of corruption

- Introduce national and international laws aimed at punishing corruption
- Perform proper screening of contractors and suppliers, including the possibility of blacklisting
- Conduct regular and independent audits based on the data provided during the procurement process
- Collaborate with independent investigation agencies

Innovation-Friendly and Whole-Life-Cycle Oriented Procurement

Traditionally, public procurement has largely relied on design-bid-build schemes with a strong **tendency towards the lowest bid.** This focus on initial construction costs not only neglected the total cost of ownership, but also seriously inhibited innovation and productivity improvements. The traditional approach is gradually being replaced, however, as governments start to see the **merits of DB and PPP,** and introduce more flexible and outcome-oriented bidding requirements. The new procurement models are being used in numerous major public-sector projects worldwide – including *Crossrail*, one of the world's largest infrastructure projects.

To improve bidding schemes in respect of innovation and construction performance, a government should first review the asset and process specifications in light of newly available technology and materials, as well as other procurement objectives such as total-life-cycle cost and sustainability.

Innovation-Friendly and Whole-Life-Cycle Oriented Procurement

On the basis of that assessment, several steps can be taken to create the right incentives for bidders:

- Introduce more flexible bidding and contracting models with improved risk sharing, such as DB and PPPs

  EXAMPLE: *Seattle*'s largest water-treatment facility, which provides 70% of the city's drinking water, was procured on the basis of a design-build-operate contract. That produced cost savings of 30% relative to the city's initial estimate and enabled state-of-the-art water-treatment technology that had previously been inaccessible to the public sector.

- Engage in performance-based procurement (including such factors as sustainability criteria)
- Integrate TCO and life-cycle costing into bidding requirements, and link operator payments to KPIs

  EXAMPLE: An *EU Directive*, in force since February 2014, allows the **procurement of projects on the basis of cost-effectiveness throughout their whole life cycle.** This reflects a shift towards longer-term, holistic thinking, and a shift away from a focus on initial cost.

- Require that answers to requests for proposals make reference to new technologies and building materials

  EXAMPLE: The *United Kingdom* requires the use of fully collaborative 3D BIM (with all project and asset information, documentation and data being electronic) on government projects by 2016.

- Ensure compliance with labour standards; for example, ensure that the work is carried out in a safe physical environment, in conditions that respect workers' rights as defined in national laws and international conventions

  EXAMPLE: In the *International Labour Organization Declaration of Fundamental Principles and Rights at Work*, core labour standards are defined, covering four areas:

  i. elimination of forced or compulsory labour
  ii. elimination of child labour
  iii. elimination of discrimination in respect of employment and occupation
  iv. freedom of association and the effective recognition of the right to organize and the right to collective bargaining

5. The Way Forward

The E&C sector will remain a cornerstone of the world's economy and of almost all other industries, since they rely so heavily on buildings or infrastructure assets. It will continue to define our daily lives in so many ways, because our homes, our workplaces and the means of travelling between them are all components of the built environment.

E&C has been far slower than many other industries to adopt new technology and is only now beginning to undergo a modern transformation. Its labour productivity, static for decades, is on the increase at last, and should surge once the new digital technologies are more widely adopted. The industry has also been slow to adapt its business strategies, but companies are now starting to pay more attention to a building's total life-cycle cost, for instance, and to be more amenable to partnering with other companies. Project owners and investors will have an important part to play here.

The new era in construction will bring great benefits: for the wider society, by reducing construction costs and adverse social effects; for the environment, by improving the efficient use of scarce materials or by reducing the adverse environmental impact of buildings over time; and for the economy, by narrowing the global infrastructure gap and boosting economic development in general. This potential will blossom very soon, and very dramatically. In fact, profound changes are already taking place, though not yet on a sufficiently wide scale. More remains to be done.

Sustainability, Productivity, and Cost Effectiveness of C

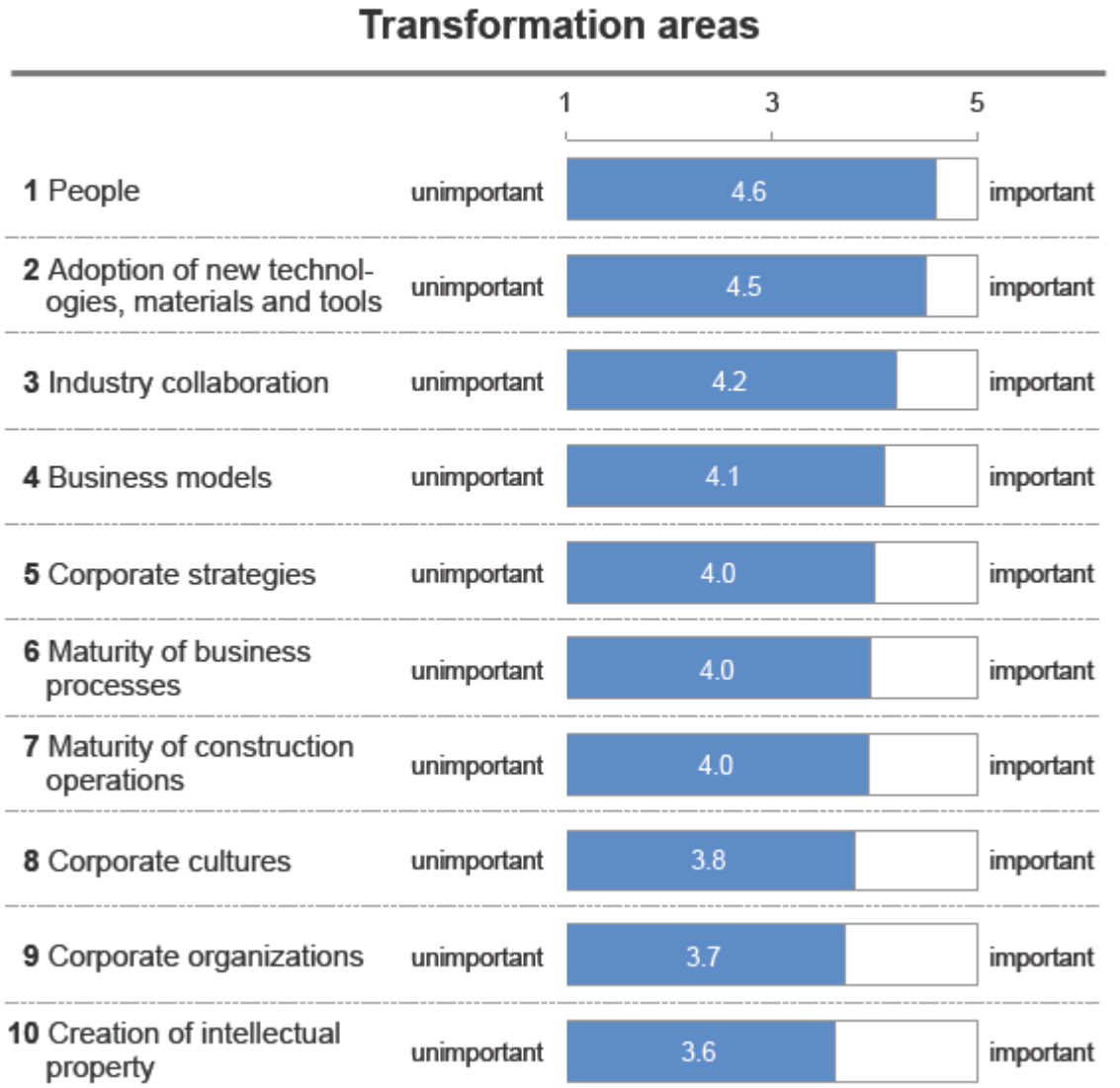
5. The Way Forward

Imperative for action

All stakeholders along the value chain – individual companies, the industry as a whole (and associated experts in civil society and academia) and governments – should take action to move the industry forward.

Private companies should actively shape the transformation. For their own purposes, they should assess the opportunities inherent in the new technologies and materials, and then adjust their processes, operations and even business models accordingly. If companies structure their organization optimally, they stand the best chance of success when implementing the opportunities on a large scale. The transformation areas of the E&C industry, ranked according to their importance, are listed in Figure 17, based on a survey conducted as part of the Future of Construction project.

Figure 17: Importance of Different Transformation Areas for the E&C Industry



The industry as a whole should enhance coordination and cooperation across the value chain, and agree on common goals and standards. And to gain the support of society at large, the industry again needs to work collectively with all stakeholders, along multiple dimensions.

The government, finally – both as regulator and often as key project owner – should create a fertile environment for the transformation of the E&C sector. High-profile projects, such as *Crossrail* in the United Kingdom, show how public projects can spread and speed up the adoption of new technologies throughout the industry.

Many of the issues and challenges are common across the construction industry, but overall the industry remains very diverse and fragmented. Companies have very varied circumstances and starting points, according to their region, the sector they are active in and their size. So the numerous developments and measures discussed in this report, even though described holistically as parts of a single transformation framework, will not all be equally relevant to any particular company. Companies have to choose the innovations and action areas that best suit their own ambitions and their clients' needs. Provided they do choose wisely – and pursue the choices actively and astutely – they should secure their own future, and ensure a flourishing and exciting future for the entire industry that they represent.

Thank-you for Listening!

Existence of a problem is chance for an opportunist to be successful.

(Shad)