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Minimizing the influence of coronavirus in a built environment

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# MODERN CONSTRUCTION: LEAN PROJECT DELIVERY AND INTEGRATED PRACTICES

## Construction management in the post-pandemic era

# Contents

# 1. Overview of the Construction Industry worldwide and in Estonia.

## 1.1 Background on Industry Performance

The construction industry has traditionally been one of the largest industries in the United States. As reported by the Bureau of Labor Statistics (BLS), U.S. Department of Labor, the value of construction in 2006 was $1,260,128 billion, representing 8% of the gross domestic product (GDP) (Figure 1). The industry employed approximately 7.614 million people in 2007 (Figure 2). By its very nature construction activity in the United States has not been subjected to the trend toward offshoring that has plagued both the manufacturing and service industries. The BLS report titled "State of Construction 2002-2012" forecasts that 58.4% of U.S. jobs will be construction-related at the end of that decade. Although other industries have blazed a trail to higher levels of quality and performance, most of the construction work is still based on long-established techniques.

Construction productivity has been lower than that of other industries. The BLS does not maintain an official productivity index for the construction industry, the only major industry that is not tracked consistently. Productivity in construction is usually expressed in qualitative terms and cannot be analyzed scientifically. A number of independent studies estimated that construction productivity increased between 1966 and 2003, at a rate of 33%, or 0.78% per year.

This productivity growth is less than one-half that of U.S. nonagricultural productivity gains during the same period, which averaged 1.75% annually. An estimate by the National Institute of Science and Technology (NIST) points to a decline in U.S. construction productivity over a 40-year period to 2007 that was -0.6% per year, versus a positive nonfarm productivity growth of 1.8% per year. The increased productivity may be attributable to mechanization, automation, prefabrication, less costly and easier to use materials, and a reduced actual cost of labor.

Most of the improvement in construction productivity has been the result of research and development (R&D) work in the manufacturing industry related to construction machinery. Earthmoving equipment has become larger and faster; power saws have replaced handsaws. However, as the use of power tools increases the consumption of energy, their contribution to productivity improvement may be eroded.

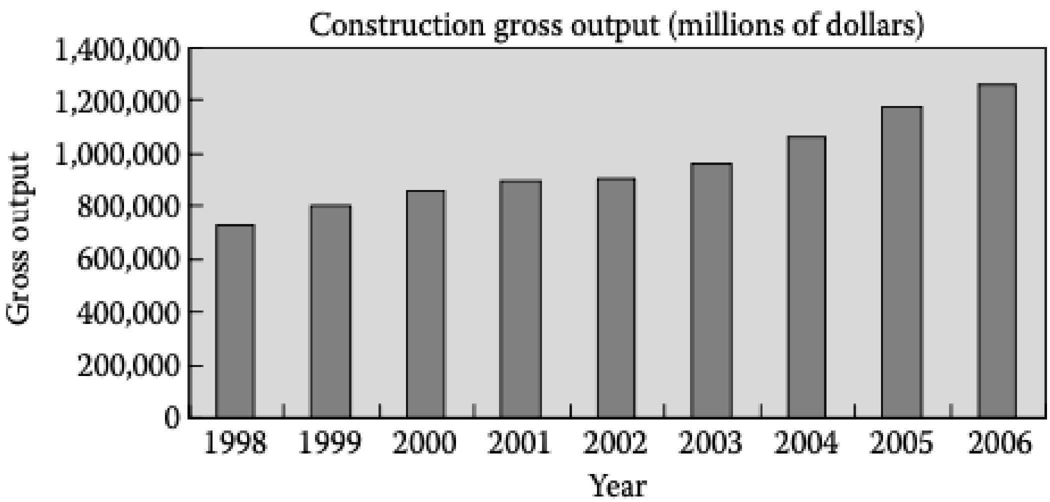


**FIGURE 1 Construction gross output 1998-2006.**

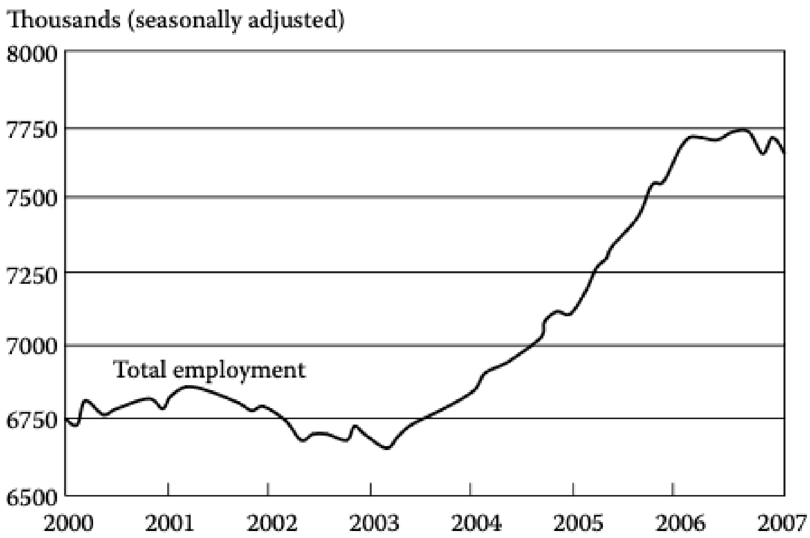


**FIGURE 2 Construction employment: 2000-2007. (Courtesy of the U.S. Department of Labor, Bureau of Labor Statistics.)**

Tilt-up construction is one example of a technology that has improved construction productivity. According to the Tilt-up Concrete Association, tilt-up construction has proven to be a fast and economical construction methodology for small buildings of one to four stories but is far from new. It became popular in California in the late 1950s, initially for warehouses, then its use subsequently extended to shopping centers, churches, townhouses, and so on. Successful introduction of the technique is credited to one Robert Aiken who constructed several buildings using "lifting jacks" to raise building panels in Illinois and Ohio. It is believed by some that a Roman architect discovered — 2000 years earlier — that it would be easier to "cast a slab of concrete on the ground, then hoist (tilt) it up into position, than to build two wood forms. Place concrete between them, and then remove the forms."

## 1.2 Reasons for Low Productivity

There is evidence that improved productivity is related to the levels of R&D in an industry, but the extent of R&D effort in the construction industry has remained very low in the United States. The overall productivity in construction has been affected by regulatory controls, the environment, climatic effects, cost of energy, and other factors. Productivity improvement has never been the focus of the construction industry, due to the lack of a model that can fit together all the fragmented components of the overall construction process.

Productivity in the construction industry is largely unmeasured, and those measures that do exist are contradictory and conflicting. Research has pointed to a significantly high level of wasted resources in the construction industry—both human and material (Figures 1 and 2). An article titled "Construction and the Internet" in *The Economist,* dated January 15,2000, noted that up to 30% of construction costs are due to inefficiencies, mistakes, delays, and poor communications.

- The Construction Industry Institute (CII) estimates that in the United States, 10% of project cost is spent in one rework
- Between 25 and 50% of construction costs is lost to waste and inefficiencies in labor and materials control
- Losses are incurred in errors in information when translating designs to actual construction. Inadequate interoperability accounts for losses of $17 to 36 billion per year. This problem is due to communication difficulties between software used by different operators in the design and construction supply chain.

## 1.3 Need for New Approaches to Construction

Global competition is increasing rapidly; in 2007 construction contracts won by Chinese companies increased in the United States and Europe by 160%. In the case of the United States, this trend would suggest that the competitiveness of domestic construction organizations is challenged on its home turf. Construction spending is moving east to China, India, the Middle East, and Africa (CRIMEA). Construction organizations that are the most competitive are likely to benefit from this trend.

Innovative approaches are urgently required to address the construction industry's ills. Construction needs a greater sense of mission, focus, and industry support. There are several obstacles to its competitiveness in the United States:

- Declining productivity
- A mindset for minimum first cost
- Prescriptive standards and codes that stifle productivity.

The industry needs more R&D, and to move beyond a reliance on historical surveys to identify new approaches for getting the job done. This problem is not confined to the United States. Sir John Egan's report in 1998 "Rethinking Construction," identified many shortcomings in construction practices in the United Kingdom and advocated radical change. The government in the United Kingdom appointed a construction task force that was comprised of a chair and nine members representing senior representatives of construction organizations and their clients. The task force studied several industries, including auto manufacturing and grocery retailing to accomplish the following objective:

- Quantify the scope for improvement of construction efficiency
- Examine current construction practice and assess the potential for its improvement by way of innovation
- Identify specific actions and good practice that would help achieve more efficient construction
- Identify projects that might help to demonstrate the improvements that can be achieved.

Sir John Egan's 1998 report, also called "The Report" made positive observations about the UK construction industry, citing its ingenuity and capacity to handle difficult and innovative projects (Egan 1998; Table 1). At the same time, the report pointed to many industry weaknesses such as: low profitability, the urgent need to train the workforce, inadequate R&D investment, and clients' misunderstanding of cost and value relationships. At the heart of the report was a desire to develop a change of style, culture, and process in the industry as opposed to recommending mechanistic activities. Proverbs, Holt and Cheok (2002) conducted a follow-up analysis of fifteen recommendations from the Egan report, using a sample drawn from the Managing Directors of 100 UK contractors. The study was intended to rank the recommendations regarding the construction industry based on a) Impact, Le., potential effectiveness (b) Effectiveness, i.e., the potential to achieve the intended purpose, and (c) Perceived potential for success, computed as the product of scores for impact and effectiveness.

- Impact was correlated most highly
- with Development of long-term relationships
- Commitment of leadership from all parties
- Greater customer focus and more and better training
- Effectiveness was correlated most highly with
- Development of long-term relationships
- Commitment of leadership from all parties
- Improved quality and fewer defects
- Perceived potential for success was correlated most highly with
- Development of long-term relationships

- Commitment of leadership from all parties
- Greater customer focus and more and better training.

**TABLE 1 Construction Initiatives**
**(*Source:* Adapted from Proverbs, Holt, and Cheok, Summary of J. Egan, Report, *Rethinking Construction,* 2002.)**

Construction Initiatives

| Number | Recommendation |
|---|---|
| 1 | The commitment of leadership from all parties |
| 2 | Greater customer focus |
| 3 | Application of products and services from other industries |
| 4 | Promote best practice in health and safety |
| 5 | Provide decent working conditions and promote people as the construction sector's greatest asset |
| 6 | Measure and assess own performance, set performance targets, and share information |
| 7 | Development of an integrated process instead of reliance on convention |
| 8 | Improved quality and fewer defects |
| 9 | Use of demonstration projects to develop and illustrate innovations |
| 10 | Rethinking (i.e., reengineering) the construction process |
| 11 | Adopt lean thinking as a method of sustaining performance improvement |
| 12 | More and better training |
| 13 | Development of technology (e.g., standardization and prefabrication) |
| 14 | Development of long-term relationships |
| 15 | Greater use of performance improvement tools and techniques (e.g., value management, benchmarking, etc.) |

These findings supported the recommendations of the Egan Task Force.

In the United States, the need for innovative methods to improve construction performance is underscored by the ongoing and anticipated shortage of skilled labor in an industry that is highly labor-intensive. Studies have shown that the traditional sources of workers—vocational school programs and apprenticeships—have not been keeping up with the demand. In the area of technicians and equipment operators alone there is a projected shortage.

Private and public organizations in the United States have been concerned about construction cost and quality for many years. The Construction Users Anti-Inflation Roundtable was formed to investigate the causes of inflation in the cost of construction. In 1972, this organization joined with a number of others to form the Business Roundtable, represented by the presidents of the 200 largest U.S. companies. This initiative led to the creation of the Construction Industry Cost Effectiveness (CICE) project to promote quality, efficiency, productivity, and cost-effectiveness in the construction industry. The CICE produced a January 1983 report titled "More Construction for the Money." The CICE report observed that construction was a $300 billion activity at that time, and that even a modest application of the teams' recommendations could save the industry at least $10 billion annually. The report revealed deficiencies in the planning, design, and construction of projects and that there was slow acceptance and use of modern management methods to plan/execute projects. In particular, owners are unwilling to bear the costs of modern systems.

The CII was created in 1983 at the University of Texas-Austin. The CII has conducted many research studies on construction productivity during that time to the present.

## 1.4 Causes of Poor Construction Industry Performance

The observations of the CICE project in 1983 are still relevant in 2010 and beyond. The study teams noted that "more than half the time wasted in construction is attributable to poor management practices." They concluded that "if only the owners who pay the bills are willing to take the extra pains and often pay the small extra cost of more sensible methods, they would reap the benefit of more construction for their dollars." The waste in construction occurs mostly in the interaction between trades. The self-interest of parties makes them put themselves first.

The construction industry is not unified on the measurement of productivity or overall performance. Many researchers define construction project success in terms of (a) cost: within budget, (b) schedule: on-time completion within schedule, (c) safety: high safety levels—few or no accidents, and (d) quality: conformance with specifications and few defects. Some view quality as one point of a triangle with cost and schedule; quality is often the first to be sacrificed in favor of cost savings and schedule reductions. Many contractors believe that it is impossible to meet desirable benchmarks in all four factors simultaneously and that there is a zero-sum relationship between them. In other words, an accelerated schedule results in an increased cost and lower levels of safety and quality. Material waste is a significant factor in construction costs—9% by weight in the Dutch construction industry and 20-30% of purchased materials in the Brazilian construction industry. Material waste is caused by several sources such as design, procurement, material handling, operations, and so on.

At least four main elements are important to overall performance:

1. Productivity: primarily measured by cost, satisfactory productivity is work accomplished at a fair price to the owner and with reasonable profit for the contractor
2. Safety: accident-free projects
3. Timeliness: on schedule and everything on hand when needed
4. Quality: conformance to specifications and satisfying owner's needs.

In terms of the prevailing industry practices, the concept of construction performance does not emphasize productivity and quality initiatives. The work of many researchers has revealed an industry tendency to measure performance in terms of the following: completion on time, completion within budget, and meeting construction codes. Little attention is directed to owner satisfaction as a performance measure. Although the Malcolm Baldrige National Quality Award was established in 1987, no construction- related organization has won this coveted award during the 20 years of its inception.

There is a growing emergence of subcontracting. In effect, so-called general contractors perform the role of construction manager, with individual contracts, and with specialty subcontractors. The subcontractors are often priced in a manner that does not reflect the general contractor's agreement with the owner; even if the owner pays a high price, the subcontractor may still have to work with inadequate budgets, often compromising quality as a result. Safety is a major source of waste. In the year 2006 alone, construction accounted for approximately 21% of all deaths and 11% of all disabling injuries/illnesses in the workplace (BLS 2006).

Poor communication inhibits productivity. Communication tends to be via the contract. The designer is paid to produce a design expressed in the form of specifications and drawings. The contractor is expected to use these as a means of communication and produce the completed facility. This communication often does not work as well as it should.

There are large gaps between expectations and results as perceived by construction owners. Symbolically, Value (V) = Results (R) - Expectations (E). Consequently, since expectations often outweigh the results, construction owners feel that they receive less value than they should. Studies to quantify the gaps or dissonance zones between the three parties to construction (i.e., owners, designers, and contractors in health care facilities projects), revealed significant differences between them (Forbes 1999) In the area of owner satisfaction factors for example, public owners and designers differed on seven of nine criteria, owners and contractors differed on five of nine criteria, while designers and contractors disagreed on the relative importance of two criteria.

Innovation is adopted very slowly. Small contractors often lack the expertise or financial resources to adopt technological advances—adoption is inhibited further by fear and uncertainty. Roofing contractors, for example, tend to use the same time-honored methods to ensure that supplies and equipment are on-site each day. Expediters, at additional cost, deliver items that are frequently forgotten.

Needed training often does not get to the decision makers in the construction industry. Construction management (CM) programs around the country have been providing higher levels of training for managers; however, this training has not reached the ultimate decision makers in the industry. Efforts to enhance quality and productivity are likely to be frustrating under this scenario.

Owners have not specifically demanded productivity and quality. There is a general lack of productivity/quality awareness in the industry among all parties, including owners. Owners have come to accept industry pricing—they have not been able to influence the productivity of the industry—prices have simply trended upwards with fluctuations based on market conditions. By contrast, manufacturing activities have become cheaper over time on a per unit basis.

Architect/engineer contracts are unclear with respect to professional standards of performance, often leading to unmet expectations. Construction owners feel that typical A/E contracts protect designers at the owner's expense. For example, prevailing contract language relieves designers of any role in the case of a lawsuit or arbitration between an owner and contractor. An outgrowth of this is the practice of "substantial completion" where a facility is usable but may have a small but significant percentage of remaining work in the form of a "punch list". An owner often has a tough time in persuading a contractor to finish that work.

Few large design or construction companies, and no small companies, have implemented the concept of a quality or productivity manager—cost cutting trends have resulted in such a position being viewed as an unjustifiable luxury. On the positive side, there is a growing interest in lean construction techniques, and as of 2010, a small number of projects have been conducted based on a lean approach. However, the deployment of these methods is mostly driven by consultants, as "lean" is still in its emerging stages.

There is little, if any, benchmarking — many manufacturers and service organizations have become preeminent by adopting the best practices of benchmarked organizations. Construction has done little of this, due to distrust, fear of losing competitive advantage, but more likely, simply by being anachronistic.

Mistakes, rework, poor communication, and poor workmanship are part of an ongoing litany of deficiencies that seem to be accepted as being a natural part of construction activity. Safety is a major national concern. Construction has an abysmally poor safety record, worse than all other industries.

## 2. Current situation in the Estonian construction sector

The Centre for Applied Social Sciences (CASS) of Tartu University has highlighted in the study "Analysis of Productivity, Added Value and Economic Impact of the Construction Sector" commissioned by the MEAC prior to this work (hereinafter referred to as the Construction Productivity Survey) the important role of the construction sector in the socio-economic development of society: through construction activities, companies create wealth, which accounts for about 6% of GDP and, together with the real estate sector, 16% of GDP. The construction sector creates new jobs, supports the sustainable development of the economy and provides an opportunity to address regional, social, climate, cultural heritage and energy challenges, which is why the sector plays an important role in the government policymaking.

During general economic growth, the Estonian construction sector has grown rapidly in recent years - the construction volume of approximately 3.2 billion euros in 2018 exceeded the level of the most active construction year so far, 2007, for the first time. In 2019, the construction volumes were even higher, but according to preliminary information, in 2020 they fell again to the level of 2018.

At the same time, the construction sector is facing various problems and challenges that reduce the international competitiveness of the construction sector, for example:

- low productivity (productivity of the Estonian construction sector is twice lower than the EU average)
- reduced growth of added value
- lack of innovation
- non-transparent and fragmented processes
- cyclicality
- pro-cyclicality of public sector construction investments (increase in investment volumes in the economic growth phase and decrease in the volume in the economic downturn phase)
- lack of consideration of energy consumption in buildings and CO2 emissions in the sector
- fragmentation of the construction sector (mostly small companies)
- lack of cooperation in the sector
- shortage of skilled workforce and, on the other hand, valuing of skilled workforce - i.e., how much the sector itself values (incl. in terms of wages) trained/skilled specialists compared to an employee without professional skills
- low export potential etc.

Today's project-based approach in the construction sector leads to the fragmentation of the value chain and lacks to provide a lifecycle-wide view of a building, focusing primarily on meeting contractual obligations rather than involving a balanced comprehensive spatial solution, additional financial benefits or innovation. At the same time, shifting the focus to the construction value chain as a whole is one of the most important ways to make the sector more efficient from a broader perspective and, on the other hand, to reduce the total cost of building life.

The aforementioned challenges are largely due to the external environment and third parties (such as the public sector as a policymaker and contracting authority), while bottleneck situations create new challenges in the built environment (e.g. lack of a comprehensive vision for high-quality, environmentally friendly and healthy living environment). The principles of high-quality spatial planning developed in 2019 have not been implemented in practice. Consequently, specific steps need to be taken to understand, evaluate and make decisions based on common values and principles.

The analysis and suggestions made by the expert group on spatial development have not yet been implemented in full. In order to the further development of the construction sector in

Estonia to be uninterrupted and competitive and for the built environment to support the needs and interests of the population, it is important to create a common understanding of the vision between various parties, aimed at achieving cross-cutting goals.

The construction sector cannot be viewed as a separate industry. First, it is difficult define the clear borders of the construction sector, as the value chain of the construction industry is very wide and not limited to companies specializing in construction. For example, minerals, waste, logistics, real estate, industry and many other fields are largely dependent on or contribute to construction, but companies specialized in these activities are not classified as construction companies. Secondly, the construction industry has similar features as other industries, which means that the problems and viable solutions that promote economic success and quality are not necessarily unique here. However, there can be no doubt that for many people, businesses, countries and other potential owners, a building is usually one of the biggest investments. The result of construction will shape our living environment and society for decades, hundreds or even thousands, often exceeding the lifespan of the original owner. Due to the low recurrence, many owners cannot consider themselves proficient in making construction investment decisions, due to which the best solutions may never be implemented. It is therefore likely, and explained in this document, that there are many untapped opportunities for more skillful management of construction investments. The great development potential of the processes in the construction sector will lead to a significantly more efficient economy and a higher quality living environment. The problems and solutions presented in this document can also serve as an example for solving similar problems in other economic sectors.

## 3. Strengths of the Estonian construction sector

In addition to addressing the challenges in the construction sector, it is equally important to recognize the positive achievements of the sector and to further develop these strengths. In the whole, people's satisfaction with the condition of housing has increased, which is expected to be due to the improvement of construction quality, but also to the established construction standards. On average, the satisfaction of the Estonian population with the housing has improved by 10% in ten years.

The capacity to conduct electronic procurement deserves to be highlighted - the public procurement process is open, and it is managed through a comprehensive e-procurement platform. Public procurements are transparent, competition is guaranteed, procedures are fast and complaints are resolved quickly. The introduction of the electronic procurement system will lead to a reduction in administrative costs. In addition to the lowest price criterion, the Public Procurement Act allows for and even favors the setting of qualitative, environmental or social evaluation criteria, which help ensure the selection of a tender with the best price quality ratio. The Road Administration (from 2021 the Transport Administration) and State Real Estate Ltd., which are state contracting authorities, have carried out several successful procurements that take into account quality criteria, and the construction sector assesses the competencies of these agencies. However, there is still much room for improvement in the implementation of value and collaboration based procurement in international comparison.

The productivity of the construction sector has grown rapidly in recent years: from 2015 to 2018, the productivity of the Estonian construction sector has grown by 35%, which is a significant improvement, however, still below the European average. Added value has increased mainly in the industry of special construction works, as well as in architectural and engineering activities, the export potential of which is the largest in case of fluctuations in market demand. The successful export of timber construction, which we are by far the first in Europe, deserves to be highlighted.

The strengths of the Estonian construction sector include the implementation of smart house solutions, solutions for building wooden houses, as well as coverage with professional standards in the industry (OSKA study). The state, in co-operation with the construction sector, has made digitalization in the industry a priority (e-construction vision, development of the digital twin, developments of the building register and planning procedural environment, etc.) and has made strong progress in this regard. Professional associations and clusters function well.

PIMA report highlights sustainable investment as Estonia's strength, which has helped Estonia reduce gaps in both access to and quality of public infrastructure. In particular, progress has been made in the field of roads and electricity. The public sector has a strong and well-functioning investment management framework, which is a pre-condition for effective investment management.

# 4. Development problems

When describing the Estonian construction sector, it is important to point out the problems in the construction sector today. The following list with reasons and explanations have been prepared during analyses of the construction sector, strategies and other documents (a detailed overview of the documents is provided in the list of references) and has been complemented with input from experts in the field through interviews and workshops.

The main problems are:

1. Lack of a long-term view on living environment
2. Lack of a long-term and counter-cyclical construction investment plan
3. Lack of smart contracting entity principles and their implementation
4. Environmental sustainability and efficiency problems
5. Slowdown in export growth
6. Lack of openness to innovation
7. Low productivity
8. Bad reputation of the construction sector.

## 4.1 Lack of a long-term view on living environment

Given that the spatial development and construction are influenced by many different interests and goals of the private sector and the state, the goals and tasks of the parties regarding construction are divided between several different organizations, including government agencies and their subordinate agencies. This makes it difficult to manage the development and innovation in the construction sector.

The Department of Construction and Housing of the Ministry of Economic Affairs and Communications has a leading role here, but the following departments also have their important roles: Energy, EU and International Cooperation, Information Technology, Economic Development, Business and Consumption Environment, Mineral Resources, Transport Development and Investment, Road and Railway Resources, and External Resources. Under the governance of the ME AC, the Consumer Protection and Technical Surveillance Authority, the KredEx Foundation and the Transport Administration also contribute to the coordination of the construction sector.

In performing its tasks, the MEAC co-operates closely with the Ministry of Finance, as well as State Real Estate Ltd. and Statistics Estonia operating under the governance of the Ministry of Finance. The Ministry of Justice also plays a key role, as does the Ministry of Social Affairs together with the Health Board. The Ministry of the Interior and the Rescue Board are also important co-operation partners. In the construction industry, environmental issues receive more and more attention, with the Ministry of the Environment and the Environmental Board and the Land Board under the governance of the Ministry of the Environment playing a key role. The Ministry of Culture is responsible for architectural policy and cultural heritage policy, the Heritage Protection Act is implemented by the National Heritage Board. The role of the Ministry of Education and Research in the organization of the education system is no less important, including the Estonian Qualifications Authority, which coordinates the qualification system in the construction industry.

In addition to ministries and agencies in their area of government, local government units play an important role in making spatial planning decisions. Decisions related to the spatial plans also provide information on the development trends of the built environment in Estonia, which is the basis for shaping national construction and housing policy. In addition to the above, there is constant cooperation with professional associations and other umbrella organizations in the field, such as the Estonian Association of Construction Entrepreneurs, the Estonian Association of Architectural and Consulting Engineering Companies, the Association of Estonian Cities and

Municipalities, the Union of Estonian Architects, the Estonian Homeowners Association, the Estonian Woodhouse Association, the Digital Construction Cluster and many others.

The fragmentation of the industry has created a situation where different agencies have prepared different studies, analyses, development plans and strategies for parts of the living environment, but nobody has come up with a comprehensive strategy with an action plan and a vision for the living environment. The various sectoral development plans are also not clearly linked, and it is primarily a question of clarity and adherence to the agreements reached in the action plans drawn up to implement the strategies. For example, the construction sector has a direct link to the Estonian Strategy for Research, Development, Innovation and Entrepreneurship (TAIE) , the Energy Economy Development Plan (ENMAK) and the Transport and Mobility Development Plan. However, the construction sector as such has not been addressed in the strategic documents as a whole and thus there is no one responsible for efficiency and quality problems to address these bottlenecks.

"Estonia 2035" will play the role of such an umbrella strategy , the aim of which is to develop and support the well-being of our people so that in twenty years Estonia will be the best place to live and work, and which should provide a unified direction to policy-makers and decision-makers in various industries and to the use of the state budget or European money. In the preparation process, one of the five priorities of the Estonian state is to create a safe and high-quality living environment that takes these needs into account, as well as to create a space and infrastructure that meets the needs of society through comprehensive and high-quality planning and renewal of space, taking into account the needs of society, population change, health and environmental protection. This provides direction, but the change would require a more specific action plan on how to achieve the objectives. It has not been created so far. In the field of spatial planning, an important umbrella document is the National Spatial Plan "Estonia 2030+" with its action plan, but today this document is not linked to the activity-based budgeting system and public investment planning. The task of the National Spatial Plan is to define the principles and trends of the country's spatial development. It provides guidelines for more detailed planning to address spatial development issues at the local level. Together with the guidelines for promoting the creation and maintenance of a comprehensive and high-quality environment for the development of spatial development principles and trends, it is an effective tool for implementing the long-term principles of high-quality spatial planning and the long-term vision of improving the living environment. In this way, they find a direct output in the next level of spatial planning and are the basis for construction activities. Based on a review submitted to the government in 2020 the government has instructed the Ministry of Finance to prepare for a New National Spatial Plan. According to the review, a valid national plan was prepared in 2011-2012 both by involving sectoral expertise and by actively cooperating with stakeholders across Estonia. Over the last ten years, a number of issues have both emerged and become more specific, being strongly related to land use management. The probability that in the next five years the review of the national plan would still include a number of new implemented spatial planning objectives is not high, because mostly the plan has been implemented, for example, in the context of infrastructure construction, or has reached the final phase. Also, the new issues that have arisen (new objectives for climate and environmental goals, basic principles of high-quality spatial planning, planning to adapt to reduction, challenges in the field of housing, promoting biodiversity in changing land use situations, etc.) can no longer be resolved through amendments to the action plan but essentially through the preparation of a new plan and its action plan. Thus, in the coming years, it is necessary to start the process of updating Estonia's central spatial planning development document, which, according to the Planning Act, takes place partly through the preparation of a New National Spatial Plan, but is probably not enough for major changes.

At the same time, there is no common understanding of what we mean by a high-quality living environment and what should serve as a basis for planning the investments in the living environment. Laws that affect space do not set out the objectives of spatial development but are limited to the regulation of procedures and narrow sectoral objectives. As a result of the spatial development work group initiated by the Government of the Republic in 2019, the principles of high-quality spatial planning were formulated, which is a step forward in describing the values of the living environment.

Thirdly, the lack of a common long-term vision and agreements in the industry leads to a situation that does not consider a comprehensive approach to the life cycle of buildings and areas, the concept and approach of which are not always understood in the same way by the parties. Decisions are often made on a project- and phase basis and needs-based cooperation across the life cycle does not work because activities are limited in terms of time, funds and due to the legal framework. If the emphasis is on making each individual process as cost-effective and efficient as possible, the perspective of long-term benefits will not be addressed. Insufficient work at the design stage and the consequent change in decisions in the following stages usually reduces the final quality of the building, prolongs the completion time, is not optimal in the use phase and, in the end, proves to be more costly. For the comprehensive life cycle view, the focus is broader than the specific characteristics or processes of individual buildings, covering the functionality of buildings as integral components of a high-quality living environment. This focus will reveal the opportunities that provide long-term savings, are health sustainable, usable and accessible to all groups in society, and reduce emissions to the natural environment through efficiency and longevity.

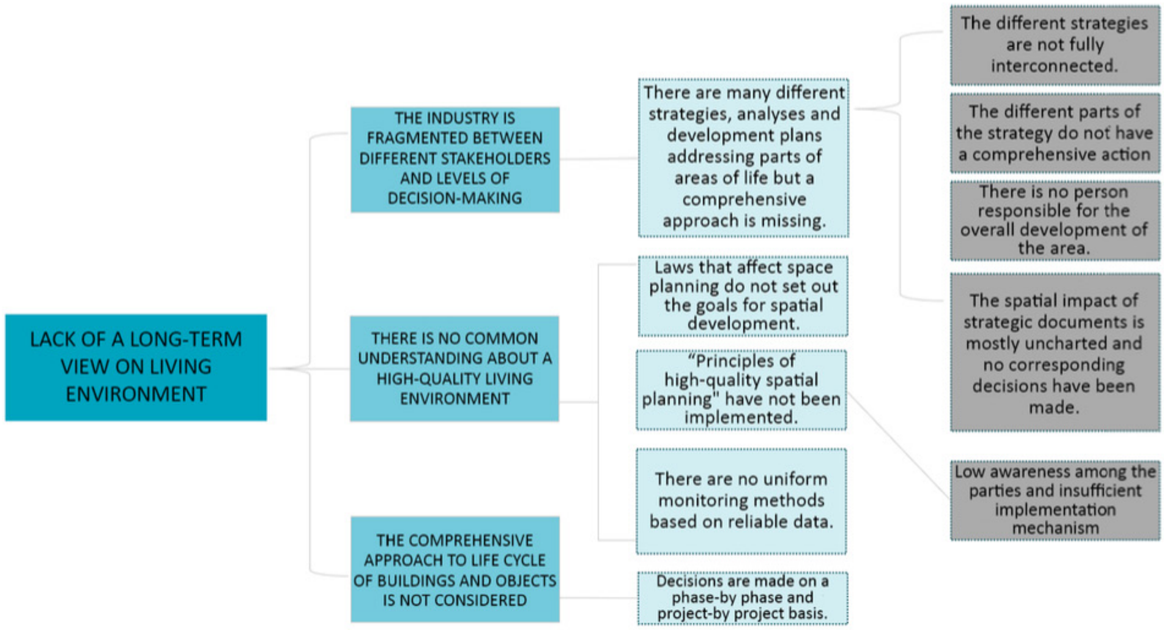


**FIGURE 3 Lack of long-term view on living environment**

## 4.2 Lack of a long-term and counter-cyclical investment plan

So far, one of the problems with the functioning of the Estonian construction and real estate market has been the pro-cyclical or cycle-enhancing capital investments of the public sector, which has led to overheating, i.e., an even stronger upturn and a sharper downturn than it would have been without public intervention. The volume of the state budget depends on the current state of the economy, the forecast of economic growth or decline, and the assessment of the economic cycle. In the recession phase, the state collects less taxes, which means that the state must find budget savings for such a forecast. One of the measures used is the postponement of investments, which in turn reduces government orders and the downturn in the construction sector deepens. In the cycle of economic growth, the state increases investments in the construction sector which leads to an additional leverage effect - prices rise, quality decreases, there is a shortage of workforce. To capture the right direction of the economic cycle, i.e., the accuracy of forecasting and taking it into account, is of critical importance. It is important to notice when the direction of the cycle changes and to react to it cautiously and counter-cyclically, thus softening sharp rises and falls.

Certainly, the lack of a long-term investment plan is related to the lack of a comprehensive long-term view on the living environment. Public investments are made in individual projects, there is no direct link between planning and investment decisions. Contracting authorities do have long-term procurement plans, but this is rather an exception; this practice is not harmonized and is not widespread in the country. In the case of construction, the area of use of the object has been considered rather than the creation of a complete living environment. This means that planning is not based on society as a whole, the conditions of a shrinking population and other regional developments are not always taken into account. Due to the shortness of the period covered by the contracts, the companies do not have sufficient security. The state budget strategy is prepared for four years, in the worst case, investments are added within the framework of the annual budget process, which means that there is no long-term investment planning at the national level. Political (individual) decisions may not support the best solutions that would be needed to develop a complete living environment, and that would promote the construction sector.

The International Monetary Fund (IMF) public sector investment analysis (PIMA) published in June 2019, points out that the Estonian state manages its investments well financially, but the long-term planning, selection, evaluation and monitoring of investments need to be improved. There is also no central overview of public sector investments, i.e., their adherence to the time and funding schedule during the development process. The lack of a long-term vision hinders the development of the country's competitiveness.

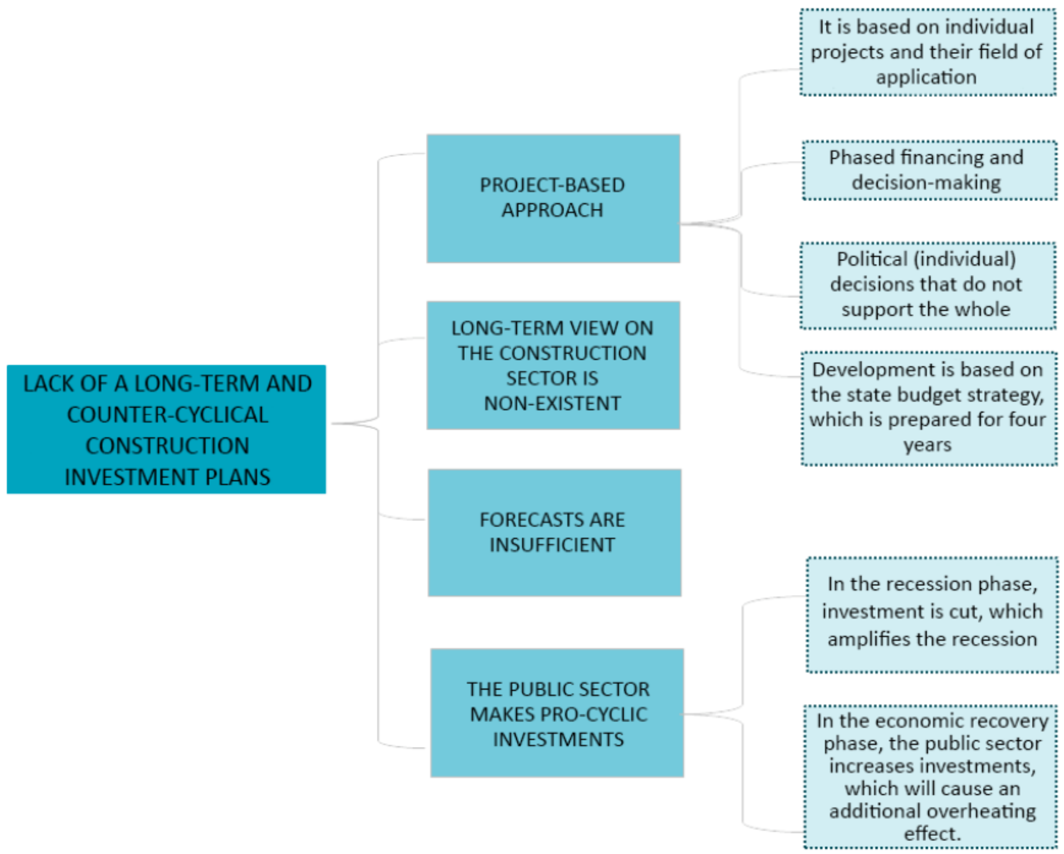


**FIGURE 4 Lack of a long-term and counter-cyclical construction investment plans**

## 4.3 Lack of smart contracting entity principles and their implementation

The principle of a smart contracting entity means the application of sufficient competence and knowledge when ordering, the ability to anticipate the whole picture and to map and manage the risks that come with construction. A high-quality building or facility starts with competent planning and terms of reference, thorough research, and an appropriate design. A smart contracting entity uses value-based, collaborative, and innovative procurements. While in the IT field we have learned to buy services based on value, then in construction the only criterion is the lowest price, which does not correspond to the meaning and requirements of the law. This is a bad practice, which in turn hampers innovation and the development of high-quality solutions. Skimping and haste in the early stages of construction will inevitably lead to time-consuming disputes and large additional costs. A shorter than needed planning period (i.e., pre-design work, including planning, pre- works, analyses) for construction projects, which is cumulatively carried over to later stages, both construction and exploitation stages, has a significant impact on the added value and productivity of the companies operating there. There are also unreasonable deadlines for submitting tenders and completing construction, without considering all the processes thoroughly enough, there is no time to find innovative solutions, deadlines are not met There is also quite a lot of delegation and multi-layered and lowest cost outsourcing that scatter responsibilities. This will result in a situation where no one is responsible for the whole. Co-operation procurement models (such as alliance procurement) have not yet been introduced in Estonia.

Often, the state and the public sector do not function as leaders and role models for smart contracting. Model practices have been partially developed in competence centers, including RKAS (for public sector real estate) and the Transport Administration (for infrastructure). Wider use of their competence in supporting local governments, for example, could also be considered, as the quality of procurement outside the centers is rather low according to the sector. On the one hand, this is due to the lack of a long-perspective and long- term investment plan described above. A project-based approach and individual policy decisions at making investments may not support the best solutions that would be needed to develop a comprehensive living environment and would result in a public sector leading the way in smart contracting. In addition, specialists with spatial planning education have been employed enough at the state level to fulfil the goal of improving the living environment and to ensure competent decision-making in terms of spatial development.

In the construction sector, the contracting authorities are both private and public sector organizations. The problem of a smart contracting entity is exacerbated by the inadequate number of trained professionals. Specialists with a certain higher education are needed by both the public and private sectors, in the case of other specialists too many people enter the sector every year. On the one hand, the lack of specialists is exacerbated by the small number of construction students in higher education and the high drop-out rate, i.e., there are not enough graduates who would come to work in the field of construction. The reasons for this can be found in the fact that construction specialties cannot compete with more popular professions (e.g., IT). On the other hand, schooling depends on the cycles of the field - during the economic downturn, there is time to go to school and study, during the economic upswing, students are already hired from the school bench and so their education path is interrupted.

More cooperation between architects and engineers is needed to create a unified value system and set goals. In all specialties dealing with space, including engineering, more strategic planning and urban planning, the connections between construction and planning, and the effects on society, the environment, etc. need to be introduced. Unfortunately, very often there is a lot of misunderstanding and the quality of cooperation suffers.

The Green Paper on Spatial Planning, too, addresses the need for training, by highlighting the following:

- to promote planner education (level training, in-service training) in order to ensure the growth of competent planning officials and planning consultants and the

competence of existing ones
- continuous training and promotion activities for planners, decision-makers, participants in planning and the general public.

Knowledge of the basic principles of high-quality spatial planning (including inclusive design) should be promoted in construction-related disciplines (not only in architectural and planning education, but also, for example, in civil engineering study). A common understanding of the goals for creating a living environment makes it possible to alleviate the conflicts of different interests in creating a built environment.

In addition to the small number of students in higher education and high drop-out rate, the seminars and discussions conducted during the analysis also highlighted as a problem that the training offered in the specialties is not practical enough or up-to-date. The reasons for this are that not enough entrepreneurs are involved in curriculum development (although they are involved in the preparation of qualification requirements or professional standard), internships are not always mandatory or good internships are difficult to find and companies do not cooperate enough with educational institutions on RDI from which educational institutions could also learn and pass on the knowledge. The weakness of the construction sector is the lack of project managers with management knowledge. Universities should pay more attention to teaching leadership and collaboration skills when designing construction specialty curricula. The shortage of trained professionals in the public sector would be improved if relevant professional experience in the public sector were taken into account in maintaining a professional level in the construction sector. At the moment, a public sector employee who wants to maintain a professional level must also work in the private sector.

Experience gained in the public sector should be taken into account in a number of specialties, such as architects, landscape architects, planners, civil engineers and engineers, in order to maintain a professional level. There are professional standards at the level of skilled workers, but there are (almost) no workers with a professional certificate. The construction business model, where a project management company hires subcontractors to carry out construction work, does not favor the certification of professional qualifications:

- the main contractor or the project management company does not want to have additional requirements (for example, that all construction workers must have proven professional skills) which prevent them from freely choosing and changing subcontractors
- the general contractor, who has the resources to train, is not interested in training skilled workers because it does not employ the workers itself
- a subcontractor, who oft n has to make ends meet without an opportunity for development, cannot afford training because it does not have the resources (money, time) and is afraid about employees leaving.

To ensure substantive quality, skilled construction workers (evidenced by a professional certificate) are needed.

According to the participants in the analysis discussions, the number of in-service training courses also does not correspond to the actual demand and need of the market. At the same time, due to high turnover and tight work schedules, company managers may lack motivation to train employees. The training simply is not cost-effective. Businesses are small and lack the necessary resources.

In the case of a shortage of skilled workforce, the current practice of companies in valuing people should be observed. To what extent does the sector itself value (incl. in terms of remuneration) a trained/skilled specialist compared to an employee without professional skills? In a sense, it is a vicious circle - companies could raise wages, but this means that the prices of services and products must be increased, and the customer must be prepared for that.

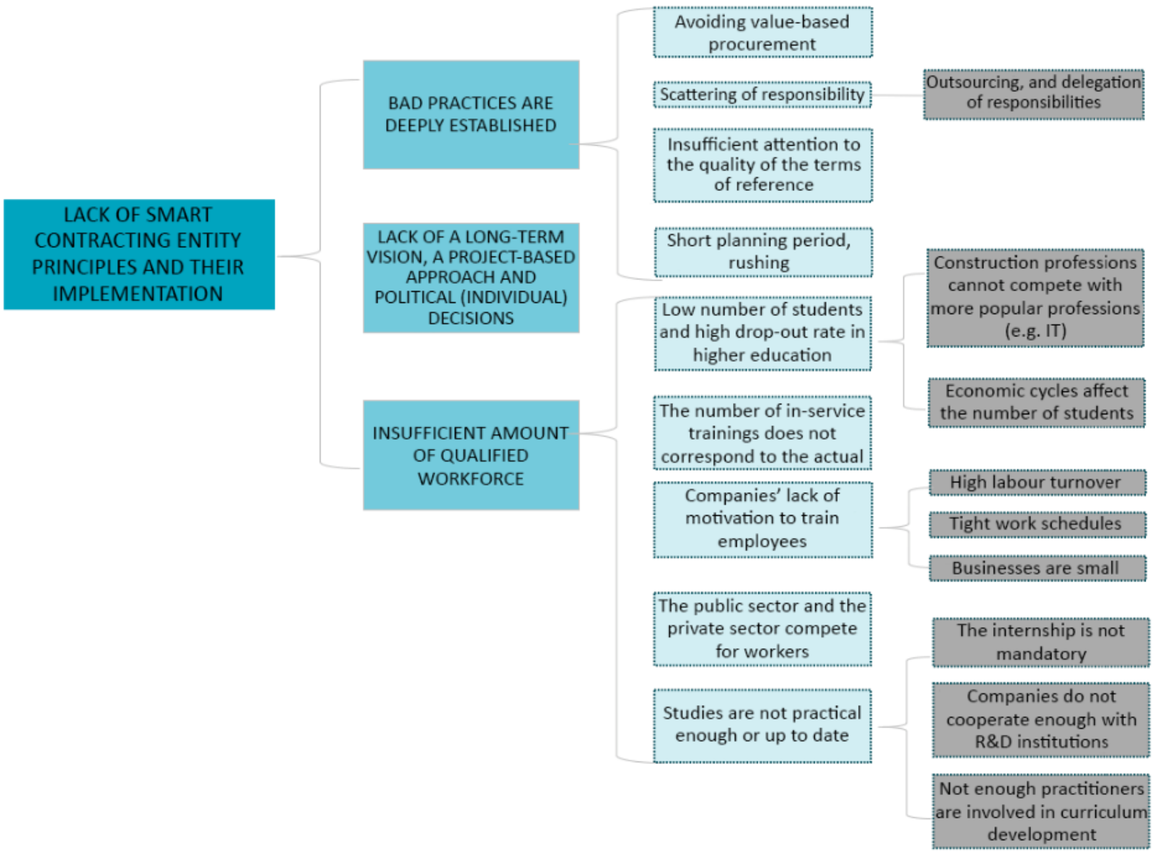


**FIGURE 5 Lack of smart contracting entity principles and their implementation**

## 4.4 Environmental and health sustainability problems

The application of the principles of environmental sustainability must be viewed throughout the construction life cycle instead of by individual stages. This means that these principles must be recognized in all activities in the construction industry - in the preparation of terms of reference, planning, design, construction, exploitation as well as demolition/renovation and handling of construction materials and products. The Estonian construction industry is fragmented, it includes vastly different fields of activity - architects, builders, consultants and engineers, specialized subcontractors. This means that informed and responsible decisions must be made at all stages and by all parties. However, the later the decision is made, the less impact it can have, or the more costly and environmentally harmful it will be. The cheapest and most environmentally friendly way is to make the right decisions during the stage of drafting the terms of reference.

Environmental sustainability is not only a concern of the contracting authority but also of the tenderer, who should achieve savings in the production process or in the provision of the service. Increasing attention, for example, to reducing CO2 emissions in production is becoming increasingly important if one is to compete in both domestic and foreign markets. As 50% of natural resources is directed into construction, the limited and fragmented view on the principles of the circular economy in the construction sector makes global resource efficiency impossible.

In the European Union, buildings consume on average 40% of all final energy consumption, in Estonia this figure is 50%. Old buildings are energy intensive, and no energy efficiency and indoor climate requirements were in place at the time of construction. Many of these buildings have not been renovated or brought into line with current requirements. One can say that addressing the reduction of energy use in the existing housing stock is not systematic and planned, there are no overviews of objects in need of reconstruction and renovation, which hinders the planning of further activities in these areas. This is partly since such data is not aggregated, information systems are not compatible with each other.

Modern construction activities are moving from open construction sites to factories. It also has a positive impact on environmental sustainability, by helping address these problems more effectively. In Estonia, this is currently manifested in a strong cluster of wooden house construction, but in terms of increased productivity in the construction sector, it is important that off-site manufacturing expand more actively to other construction areas as well.

In addition, it is important to keep in mind that in terms of societal benefits and overall costs, it is often more economical to intensify the settlements and refurbish old valuable houses in the core area of the city (even if they cannot meet the highest energy efficiency standards) instead of building efficient new buildings far from

Reducing car use is an important factor in terms of the environment and also in terms of health sustainability.

Health sustainability as a basic principle of a high-quality living environment sets the basic preconditions for the design of a building. The built environment has a significant impact on human health, productivity, and wider well-being. In 2017, a research summary analysis "The 9 Foundations of a Healthy Building" was published, according to which these foundations include ventilation, noise, lighting, air quality, thermal health, moisture, dust, and pests, drinking water quality, and safety and security (overall term indoor climate). No doubt, health sustainability also results from the implementation of inclusive design and accessible solutions. Objects that are accessible to as many people as possible ensure the long-term sustainability of the living environment, as such living environment will not need to be materially adapted to the changed needs of people in the future. The problems are usually due to insufficient preparation for construction, design or planning and the execution of work. Considering and including all these factors requires a lot of expertise and therefore, the health aspect should be fully considered when improving processes.

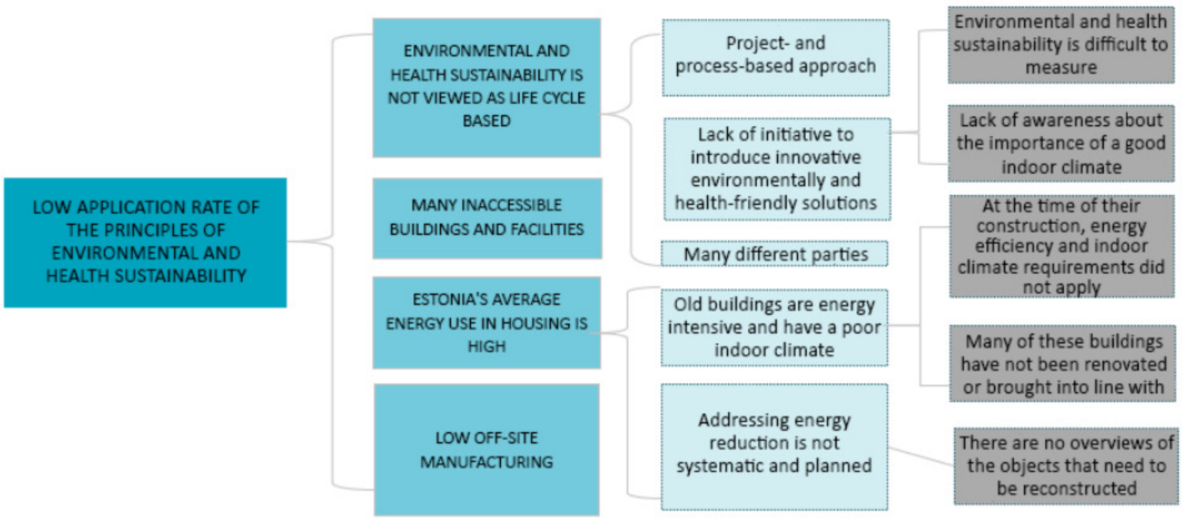


**FIGURE 6 Low application rate of the principles of environmental and health sustainability**

## 4.5 Slowdown in export growth

Empirical studies have found that companies that export and have an international or global reach are more productive, and among exporting companies, in turn, the companies export high value-added products and services are more productive. One of the most important obstacles to the growth of broad-based exports in the Estonian construction sector is the size of a company. Estonian construction businesses are small, it is more difficult for them to find both financial and human resources to enter foreign markets. Small businesses have a narrow network of contacts abroad and little international experience. Small companies also have small production volumes, which makes it difficult to compete in large markets. Although small businesses may be successful in providing specific services due to their flexibility, such success will not lead to a wider export capacity in the sector.

In addition, the operation in foreign markets is hindered by local bureaucracy, different business cultures and practices, access to information on the market, employment contracts, working conditions, legislation and tax system of destination country, and qualification requirements for employees. There is a hidden protectionist policy (e.g., foreign companies win the contracts that local companies are less interested in).

Challenges of export development include certification (documentation required for the CE mark, which needs product development and research, which, however, is not sufficient) and energy efficiency and CO2 emissions requirements. For example, without an environmental declaration or a corresponding test or calculation, it will not be possible for Estonian manufacturers of construction materials to sell their products on the European Union market in the coming years. The following factors can also be considered as barriers to exports: low automation of production, low use of digital solutions, high cost of acquiring modern production technology and high cost of raw materials, all of which lead to higher product costs and thus make competition more difficult.

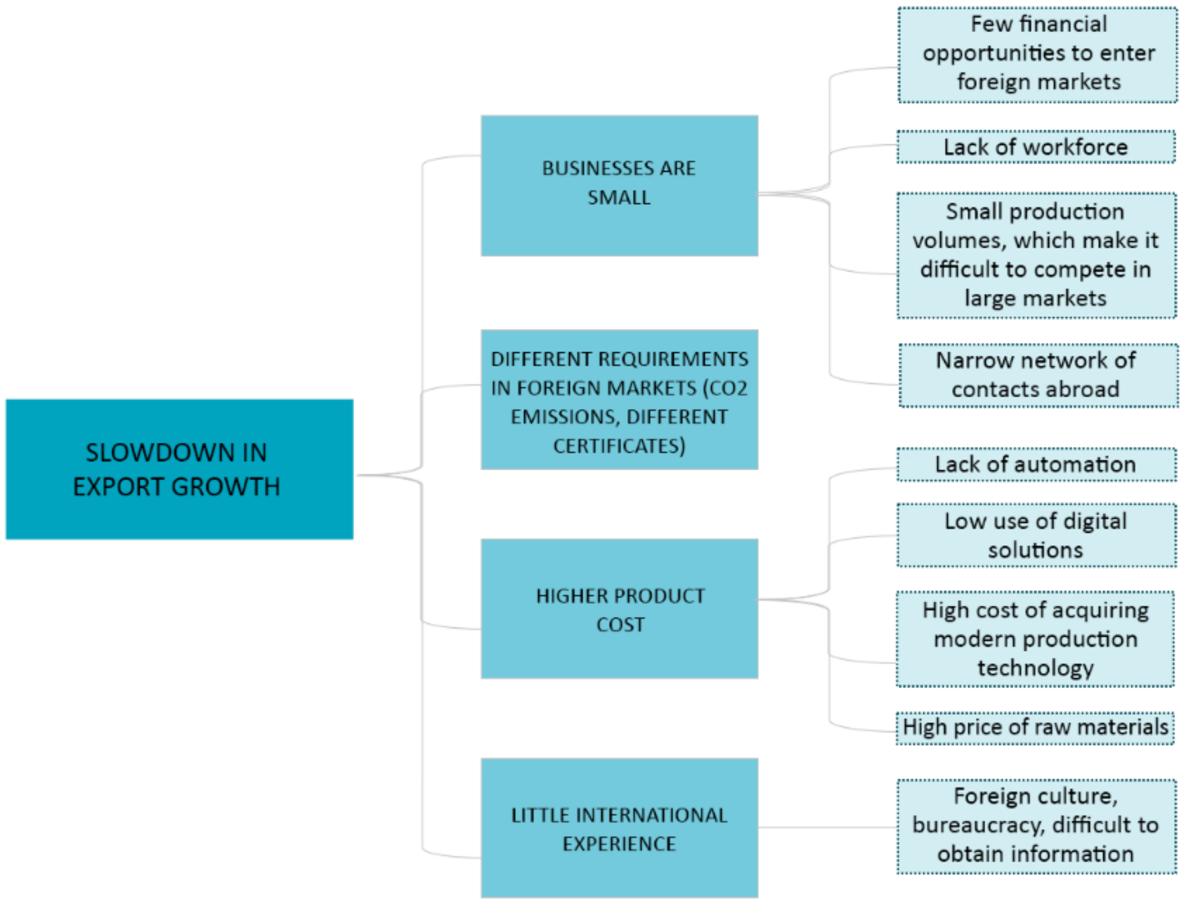


**FIGURE 7 Slowdown in export growth**

## 4.6 Lack of openness to innovation

Innovation is hampered by both the development of the living environment and the instability of the sector. As the project-based approach prevails, there is no long-term planning to offset this instability. The existence of a long-term plan and an investment plan, as well as long-term contracts, linked to an existing spatial planning system, would give entrepreneurs confidence, which would increase their willingness to invest in innovation. At the same time, public investment is made in individual projects, so companies are reluctant to make consistent investments in R&D and innovation due to the short duration of the contracts. Due to low recurrence, the profitability of innovation is lower and takes more time than it would be for large and recurrent projects. Low levels of innovation are likely to lead to lower quality investments, including an unsustainable built environment that is not guided by the principles of high-quality spatial planning.

In a highly competitive environment, companies do not have the resources for innovation in the normal course of business and in the so-called "survival process". It is, in a sense, a dead end, because a lack of innovation is not conducive to development and this, in turn, is not profitable. Companies lack substantial cooperation supporting innovation between the various parties involved in construction (client, architect, engineer, builder, manager, end-user), which is a precondition for optimizing the life cycle costs of a building. Estonian construction businesses are rather small and operate primarily in the domestic market. Small companies have low readiness and opportunities (including both financial and human resources) for innovative investments, and low export capacity. There are often too many levels of contracting, which makes the implementation of innovation cumbersome. The cooperation with other areas to adopt technical solutions or extract ideas is also insufficient.

Similarly, the cooperation with universities and other research and development centers is low. The subject of knowledge transfer is one of the main tasks of Enterprise Estonia, however, the corresponding measures have not always been attractive enough for companies or have not been found. The companies have not set a goal of involving researchers from universities and other research and development institutions in applied research projects in the field of construction.

One of the obstacles to the development of innovation is the lack of laboratories (e.g., for the determination of hazardous substances) and the non-compliance of laboratories with the requirements of construction practice. The problem can be divided into three parts: on the one hand, the required laboratory does not exist at all or the existing laboratory does not meet the requirements of practice (e.g. the laboratory is too small to take certain objects for measurement and testing) or the market is too small to set up a laboratory and therefore, it is not profitable. In the latter case, the state could consider support measures to provide companies with better access to foreign laboratories where testing is costly.

Behind the lack of innovation, we can see traditional contracting methods that focus on solving individual problems rather than achieving an excellent end goal, incl. the lean constructs principles and alliance procurement implementation is not encouraged. Due to traditions, habits and lack of information, the design philosophy of the building as a whole based on the building information model (BIM) is not sufficiently implemented.

The share of value- and cooperation-based procurement in public procurements is low compared to other countries. Long-term benefits and good results are usually not considered as main criteria - successful tenders are usually determined only by the lowest price. According to the sector, one of the main reasons for focusing mainly on the price component is the aspect of contesting procurements, i.e., if the lower price criterion dominates, the risk of contestation is significantly lower. At the same time, it also happens in the private sector that they focus primarily on the price component, so the problem is not solely public sector based. Focusing on the price component can justify companies' lack of interest in knowledge-based construction and development, as innovative solutions may be more expensive in the design and construction phase than conventional traditional solutions, while being more cost-effective in the overall lifecycle of a building. For this reason, the public sector should set an example by prioritizing cooperation and quality criteria alongside the lowest price, in order to maximize the potential benefits throughout the life cycle of the building.

An indispensable precondition for the value-added development of the construction sector is the provision of particularly good, interoperable and interconnected databases based on open data. In this case, machine learning and algorithms can come to the rescue and help design, build, and maintain a better built environment for all of us. At the same time, we can notice rather low introduction of digital technological innovations in Estonia in order to make the construction process smoother, minimize construction errors, reduce costs, and increase environmental and health sustainability.

The lack of a qualified workforce can also be mentioned as a reason for low innovation. The knowledge and skills of employees often do not allow the introduction of innovative methods, technologies, and concepts. The training of specialists is insufficient to develop and/or implement innovation and to manage innovation. The problems of the skilled workforce are due to the issues of training described above, professional higher education, but also the reputation of the sector.

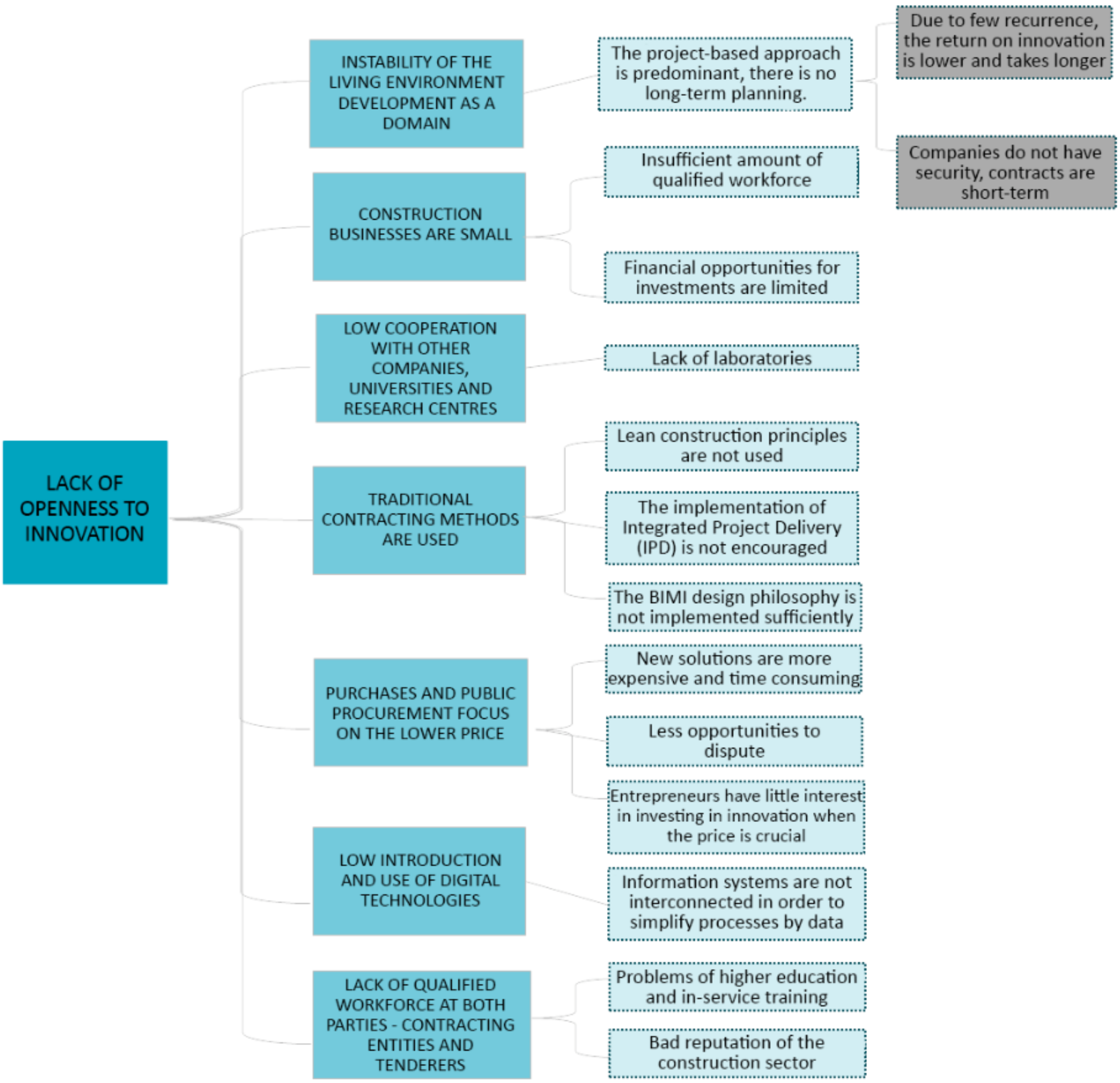


**FIGURE 8 Lack of openness to innovation**

## 4.7 Low productivity

ow productivity in the construction sector inhibits GDP growth, thereby endangering the success of other economic sectors and, in the end, decreasing the international competitiveness of the construction sector. With a high-quality service, the construction sector enables to create benefits in all other sectors of the economy and society, by creating in their workplaces and homes conditions that help increase labour productivity and thus promote economic growth and the well-being of the society. The productivity of the Estonian construction sector is twice lower than the EU average. The productivity of the Estonian construction sector has experienced robust growth, but remains below the EU average - in 2014, the productivity of the Estonian construction sector was 25,900 euros per employee, while the EU average was 50,200 euros per employee. By 2017, the productivity of the Estonian construction sector per employee had increased to 29,500 euros, but still estimated to be twice lower than the EU average.

It should be noted that in the context of this document, productivity and labour productivity are considered unambiguous. Values are calculated as the quotient of value added and the number of employees, where value added consists of operating profit, labour costs and depreciation. In the construction sector, most of the value added is included in labour costs. Thus, the comparison of the data has to take into account that the level of productivity is largely determined by the level of wages, but also by the resources invested in fixed assets (such as new machinery and equipment) and profitability. Certainly, these factors depend on the general standard of living in the region, and artificial changes can cause structural problems. For example, in the context of sharply rising construction volumes, wages of simple workforce in the construction sector may rise disproportionately high, which may reduce the competitiveness of other sectors in the labour market. However, in this paper we assume that the increase in productivity can primarily take place as a result of the more efficient work of each person. The construction sector must reduce its dependence on unskilled workforce and create high-paid, knowledge-based jobs instead. For example, almost half of jobs in the construction sector can be automated37. The increase in productivity due to the increase in added value may be due to higher construction and preparation costs, but by achieving long-term financial and quality benefits for the owner, user and society of the building. Therefore, in the case of public procurement in particular, the question of whether to order more or better buildings for taxpayers' money should be looked into more deeply. It is often not necessary to favour one over the other, but to reach a compromise between the life cycle costs and value in use. The focus on long-term benefits could also serve as a model for private owners.

The low productivity is caused by the lack of openness of the construction sector to innovation, including to technological innovation, and to the introduction of various modern digital solutions and thus to the development of modern working methods and work organization. Investment in development creates added value, and the application of innovative technologies is limited.

Productivity is also hampered by inefficient work organization. The development of companies' work culture and process management is often organized based on wasteful business models, using inefficient traditional hiring methods and contract forms. Planning, procurement and design processes are often too short, while on-site construction tends to go overdue, which reduces productivity. Often, the so-called preliminary work (feasibility studies, construction studies, identification of various conditions, etc.) is left to be carried out in the work execution phase, which inevitably results in time pressure on the performance and quality of the work. All the more so if in the course of carrying out the work, significant limitations or conditions become apparent which significantly affect the entire process and which could have been identified already during the preliminary work. Thus, a critical bottleneck is the poor quality of design and construction procurement preparation, which leads to insufficiently planned construction designs, overdue deadlines and poor cooperation between the parties. In the sector as a whole, attention needs to be paid to the various social and behavioral problems of employees, which can have a negative impact on quality and productive working time (e.g. a study found that on-site smoking breaks can reduce productivity by up to 15.2% during an 8-hour shift. This is greater than, for example, the loss of productivity due to sick leave). It should also be noted that off-site manufacturing is not widespread enough in the industry, however, inefficient construction on the site is predominant.

The low productivity is also caused by the problems mentioned in other chapters, such as the lack of a long- term view on the living environment, the lack of a long-term and counter-cyclical investment plan, the uneven distribution of investments over the years, and the slowdown in export growth. The lack of a stable, long-term and well-developed investment plan does not encourage development, export growth or investment in innovation, which is a prerequisite for increased productivity.

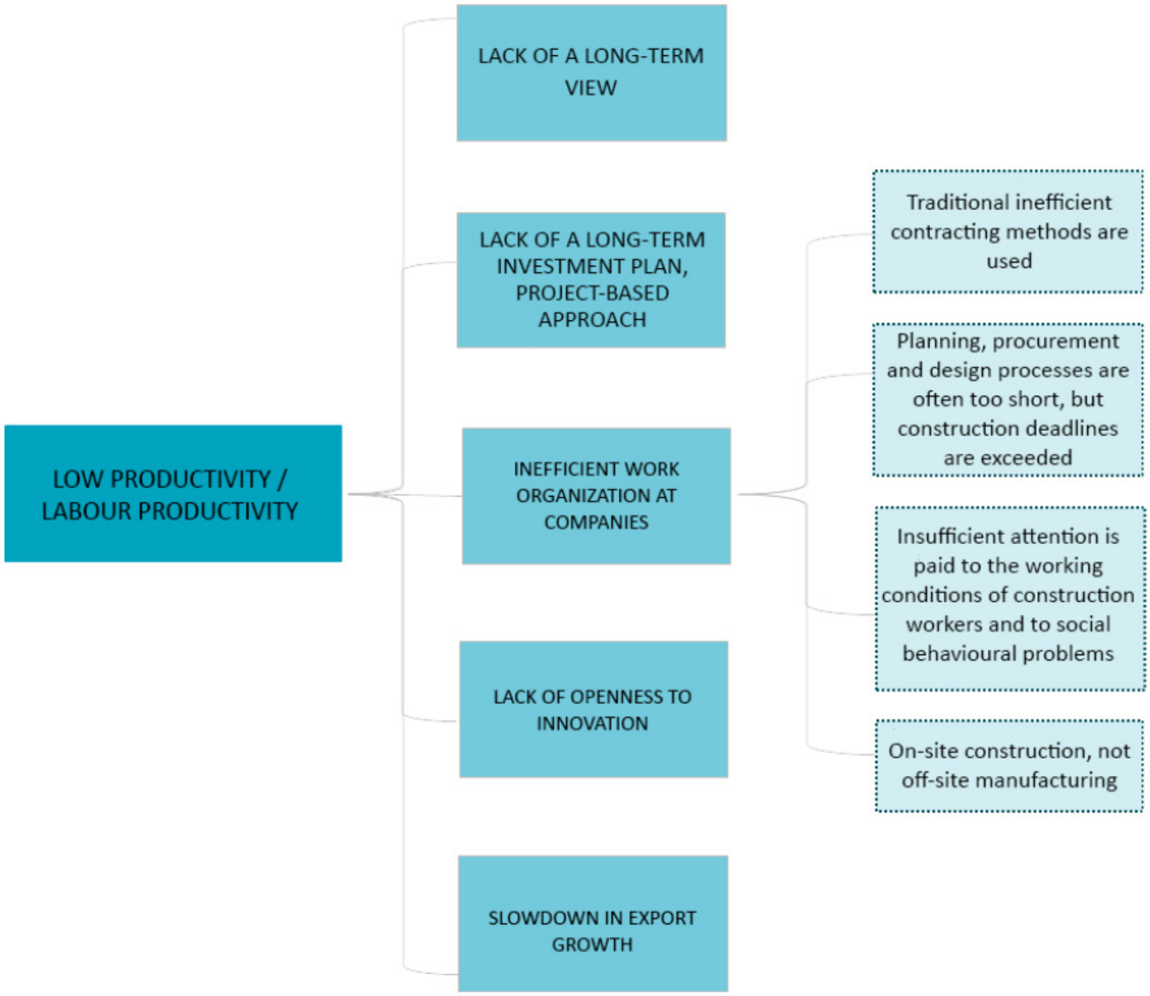


**FIGURE 9 Low productivity / labour productivity**

## 4.8 Bad reputation of the construction sector

Working in the construction sector is not valued enough in society. Cooperation throughout the life cycle of a construction is not going well, there is omission, accusation and disrespect, and a lack of involvement, all of which affect the achievement of a high-quality result and thus, the reputation of the construction sector. The principles and rules of cooperation in the construction value chain are usually set by the client, so insufficiently thought out or even faulty primary conditions affect all subsequent processes. Insufficient preparation also creates negative public perceptions of the building, which could have been of better quality by using the same resources.

The reputation of the sector has certainly been damaged by corruption cases, the issue of envelope salaries and the use of dishonest practices. More broadly, there are only a few issues in the construction sector that are covered in the media as positive examples.

Rather, they talk about non-compliance with deadlines, construction defects, accidents at work, non-payment to subcontractors, bankruptcies, visiting workers ("*kalevipojad*"), problems with foreign workforce, etc.

Many young people do not have personal practical contact with the construction industry and therefore the involvement of young people in the sector is low. The construction sector is wide, including architects, engineers, project managers, skilled workers, etc. Young people are not aware of all these roles. Physical work is not attractive and popular as a profession and cannot compete with, for example, IT or environmental protection. Negative media coverage of the construction sector further reinforces this attitude.

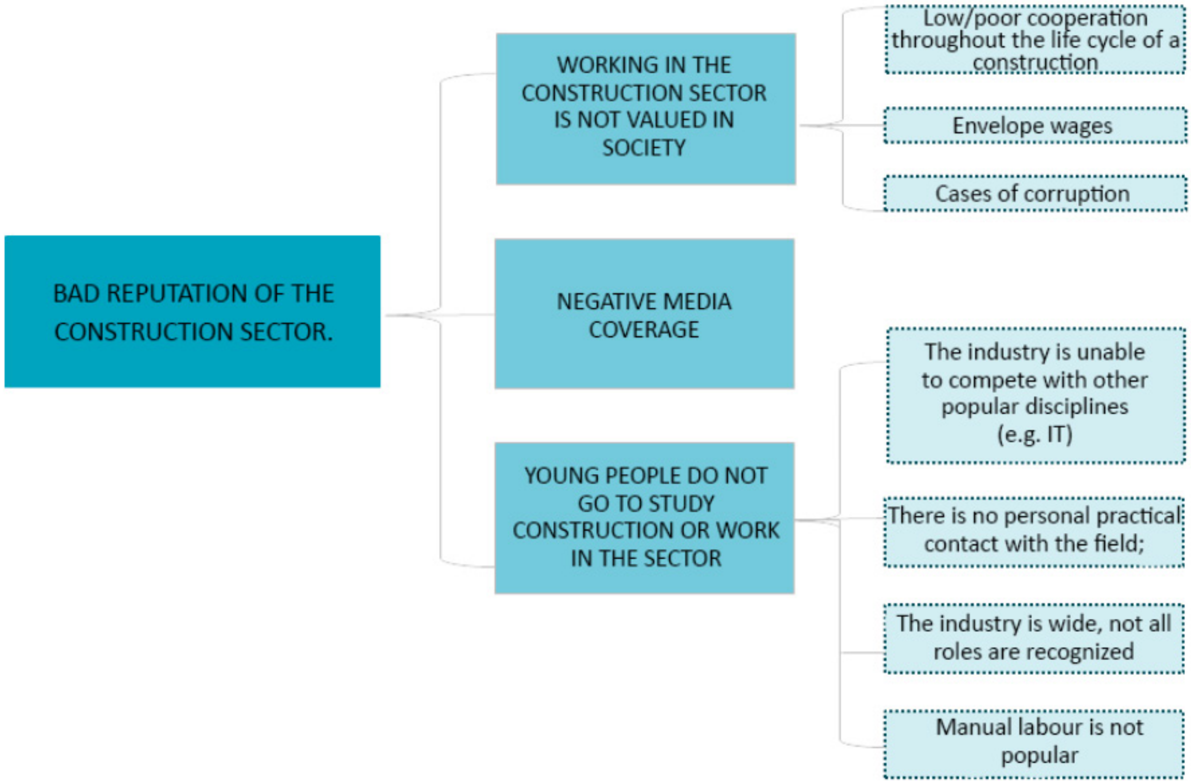


**FIGURE 10 Bad reputation of the construction sector**

## 4.9 Summary of problems and challenges

As a result of consolidating the problems and creating connections, two main problems emerge:

1. Insufficient basis for the creation of high-quality living environment
2. Low productivity in the construction sector.

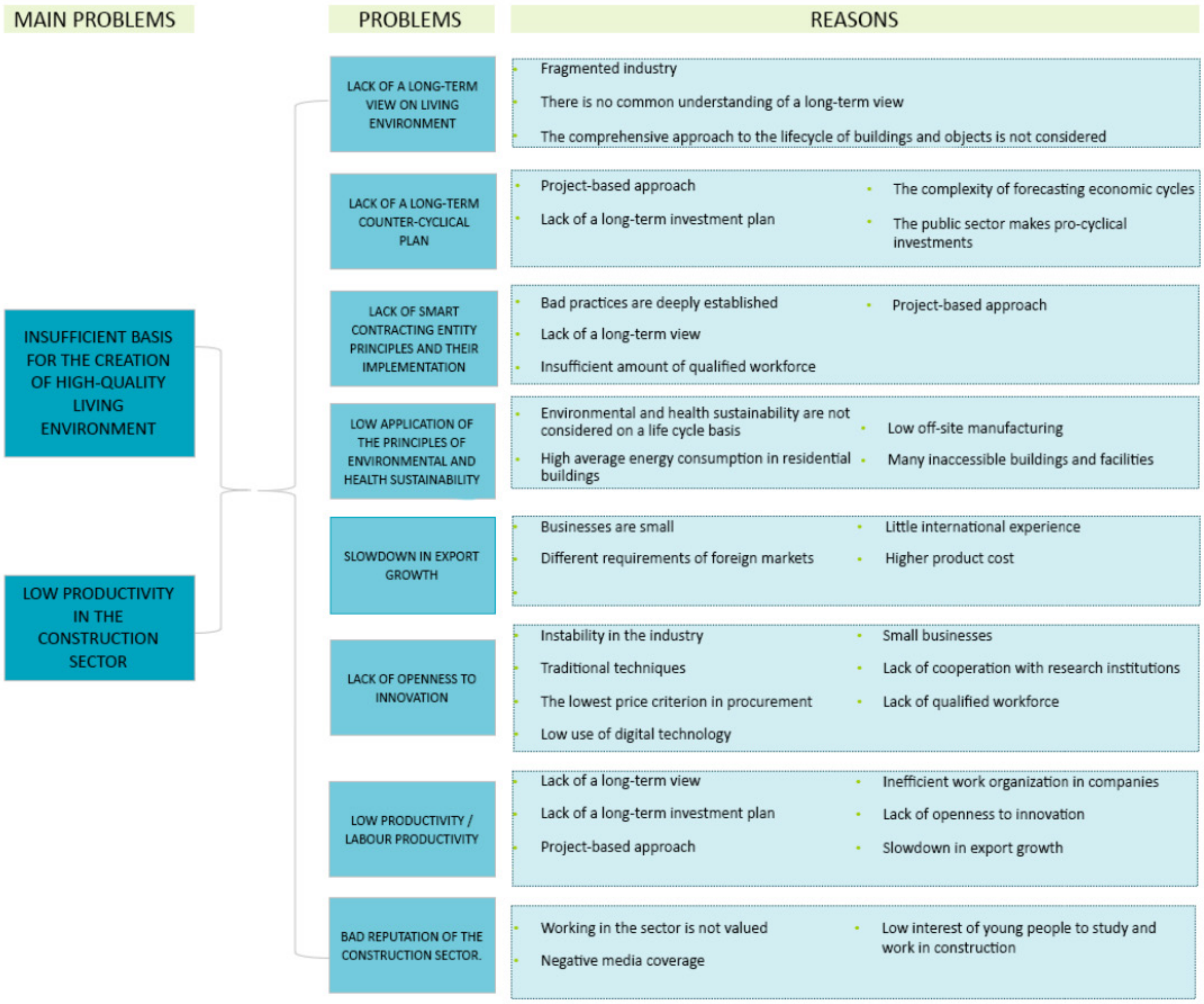


**FIGURE 11 Summary of main problems and their reasons**

## 5. Categories of Construction

In order to understand how improved methods can be applied to the construction industry, it is helpful to understand that environment; it is truly diverse, so much so that its participants have found it easy to rely on such cliches as "the industry is like no other" and "no two projects are alike," to maintain the status quo in which long-established management traditions are seen as an arcane art that others cannot fully understand. The BLS refers to three major headings: General Building Contractors SIC Code 15, Heavy Construction (except building) SIC Code 16, and Special Trade Contractors SIC 17. These are further subdivided into 11 SIC Code headings that include:

- Commercial building construction: offices, shopping malls
- Institutional construction: hospitals, schools, universities, prisons
- Residential: housing construction, including manufactured housing
- Industrial: warehouses, factories, process plants
- Infrastructure: Road and highway construction, bridges, dams

### 5.1 Who Are the Parties Involved in Construction?

The main stakeholders in the construction Industry are as follows:

1. Owners: They originate the need for projects and determine the locations and purpose of facilities. They arrange for design, financing, and construction
2. Designers: They are usually architects or engineers who interpret the owner's wishes into drawings and specifications that may be used to guide facility construction. In the design/build concept, they may be a part of the construction team
3. Constructors: These are contractors and subcontractors who provide the work force, materials, equipment and/or tools, and provide leadership and management to implement the drawings and specifications to furnish a completed facility
4. The labor force: This is comprised of foremen, craftsmen, or journeymen, and skilled or semiskilled apprentices or helpers. Many different crafts are represented, such as masons, pipefitters, carpenters, electricians, and so on
5. Major suppliers: Equipment and material manufacturers, transporters
6. Financial institutions: banks, construction financial organizations
7. Lawyers, insurers
8. Federal and local regulators: code enforcement professionals
9. Public services
10. Utilities
11. Safety professionals
12. Quality assurance/quality control professionals
13. Lean facilitators/coaches/mentors: These professionals provide support in the implementation of new lean approaches in design and construction.

# 6. Project Delivery Methods

Construction projects are described as having certain characteristics; each project is unique and not repetitious. Projects come in various shapes, sizes, and complexities. A project is said to work against schedules and budgets to produce a specific result. The construction team cuts across many organizational and functional lines that involve virtually every department in the company. The suppliers typically have a contract with the contractor, but not with the owner or designers. Government agencies oversee both the design and construction to ensure compliance with prevailing state or local construction codes.

There are a number of models for the process of designing and constructing facilities. Several of these models have been in existence for many years and have been used with varying degrees of success, depending on the type of project and the skills required.

The project delivery methods include:

1. Design-bid-build (DBB)
2. Design-build (DB)
3. Engineer-procure-construct (EPC)
4. Design-CM contracts
5. Design-agency CM contracts
6. Fast-track construction
7. Partnering
8. Relational contracting/lean project delivery

## 6.1 Design-Bid-Build Contracts

Design-bid-build contracts represent the most frequently used type of project delivery systems for most construction projects and are considered to be the "traditional" delivery method. DBB projects have the following characteristics (Figure 12):

1. The owner conceptualizes the project
2. Planning is conducted based on the objectives to be met and on economic and technical feasibility
3. Programming is conducted to identify the uses and desired sizes of various spaces, followed by a schematic design to identify relationships of these spaces relative to each other. The scope of the project, preliminary budget, and schedule are derived
4. Detailed design is usually conducted in stages, with intermediate checkpoints for verification by the parties to the project
5. The design work culminates in the preparation of completed drawings and specifications, representing bid documents as well as detailed cost estimates. The bid documents are used to solicit construction bids or are otherwise used to negotiate a construction price
6. Bid analysis is conducted and a legally binding contract is then awarded. The drawings, specifications, and signed documents then become construction documents
7. The contractor is given access to the site and instructed to proceed, based on legally established time frames. A contract may contain incentives for timely completion, as well as penalties for avoidable delays or cost overruns
8. The owner, or agents of the owner such as architects/engineers or construction managers, monitors) the progress of the construction, ensuring that interim payments to the builder/contractor match construction progress
9. At completion, there are acceptance inspections, leading to the commissioning of the facility for the owner's use. The project is turned over to the owner.

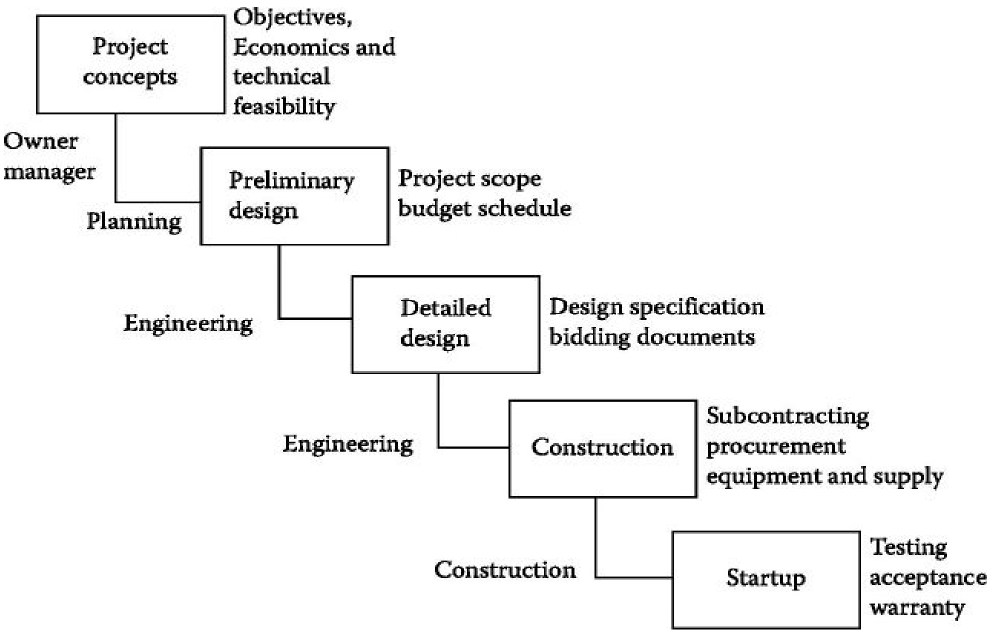


**FIGURE 12 Traditional design-bid-build construction phases.**

Design-bid-build has many well-known shortcomings: There is a greatly protracted process to do programming, design, bidding and bid award, followed by construction. Oftentimes, delays further extend the project duration and may result in cost inflation as the time extends. Litigation and disputes are very common with this method of construction delivery because of dissonance between the expectations of the three parties—owners, designers, and contractors. In many cases "absence of litigation" is one especially important performance indicator. Litigation can be an especially thorny issue for public organizations. An aggressive pursuit of claims against designers and contractors can be politically undesirable and unpleasant.

**Advantages:**

1. The design team is impartial and looks out for the interests of the owner
2. The system treats potential bidders fairly and improves the owner's decision-making ability
3. It assists the owner in establishing a reasonable cost for the project
4. Completed projects generally meet acceptable quality levels.

**Disadvantages:**

1. Design-team failures may increase the cost of a DBB project and delay it.
2. There is increased risk for the general contractor and the possibility of a compromise in quality to lower the cost of the project
3. As the general contractor is brought to the team post design, there is little opportunity for input on cost-effective alternatives
4. Pressure may be exerted on the design and construction teams, which may lead to disputes between the architect and the general contractor.

## 6.2 Design-Build Projects

Design-build (DB) projects accelerate delivery through concurrent design and construction activities. As is typical of all types of projects, a DB project is conceptualized by the owner; planning is carried out based on the objectives to be met, and on the economic and technical feasibility of the project. Site acquisition may be implemented at any point before the contract award, but is best done as early as possible to ensure that the design will not have to be aborted. Planning and schematic design are carried out by the owner's design professional, and may include infrastructure and foundation details for the project. This information allows construction to start shortly after contract award, while the design builder continues the preliminary design to obtain a final design. Typically, their design professional develops a preliminary design and cost and schedule proposals for the overall project. In some DB projects the owner may review proposals from a number of design builders and enter into a legally binding contract with one that provides the most appropriate proposal. The design builder is given access to the site and instructions to proceed, based on legally established time frames. This type of contract may also contain incentives for timely completion, as well as penalties for avoidable delays or cost overruns. The DB organization initiates construction while finalizing the detailed design. At intermediate checkpoints, verification is done by the parties to the project. The design culminates in the preparation of completed drawings and specifications that are used to complete the project. The owner or agents, such as architects/engineers or construction managers, monitor the progress of the construction, ensuring that approvals for interim payments match the progress of the construction work. At the completion of the construction there are acceptance inspections, leading to the commissioning of the facility for the owner's use (Figure 13).

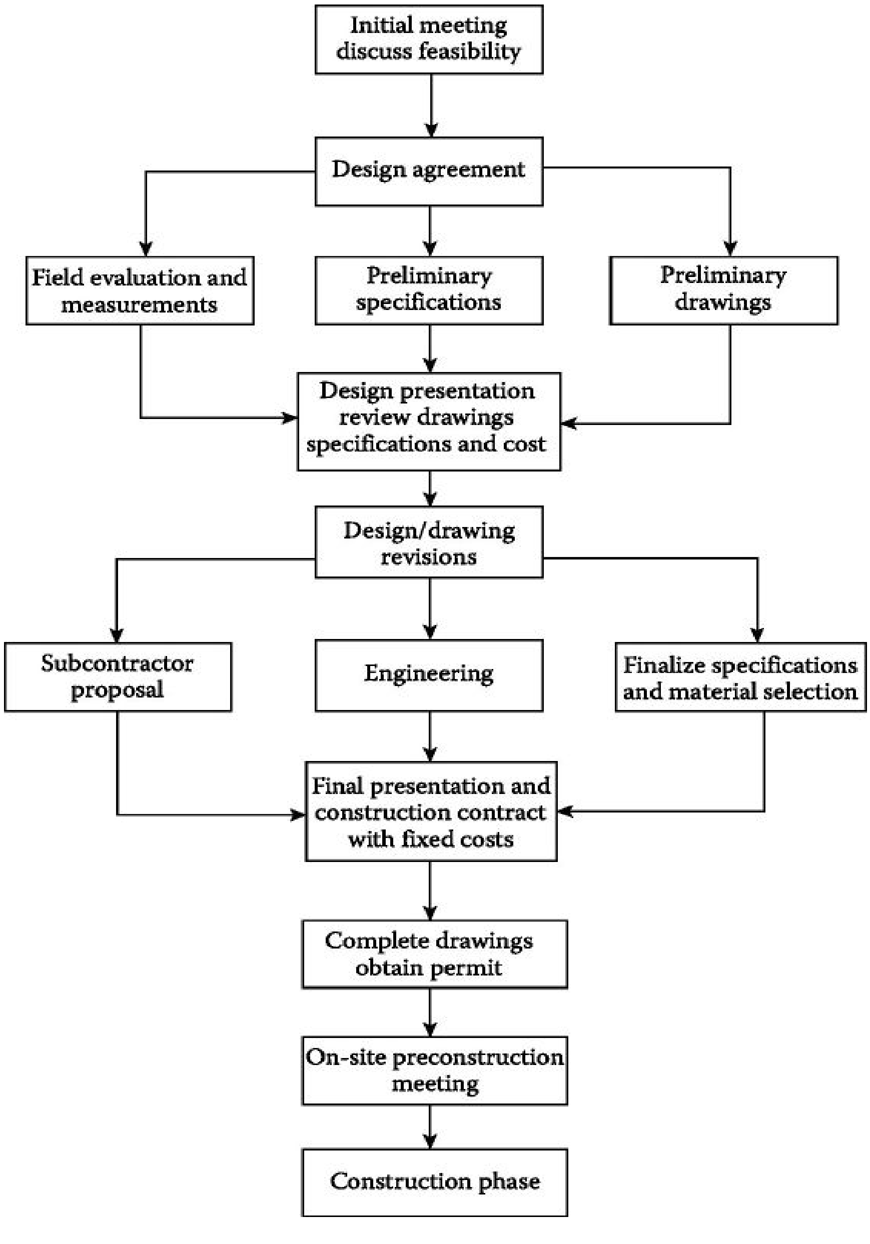


**FIGURE 13 Process flow for a design-build project.**

Design-build has the potential to provide better quality, especially with regard to the following factors that are considered to be subsets of quality: (a) communication is simplified and accelerated, as the owner has one point of contact; (b) the adversarial nature of the three-way relationship in DBB projects is avoided; (c) conflicts over the intent of the specifications and their deployment are resolved internally; (d) the accelerated completion of DB projects lends itself to greater owner satisfaction; and (e) cost growth is minimized for the owner. In order to make this potential a reality, public owners have to act in a proactive manner to secure good quality construction from DB projects, as speed and cost containment can also bring unsatisfactory quality, if unchecked. For example, the designer does not have a professional/fiduciary relationship with the owner, and may, in some instances, be required to favor the builder's needs to meet bid price limitations over the owner's needs.

**Advantages:**

1. Design-build is the fastest project delivery system
2. There is a single entity responsible for design and construction
3. There is an early cost and scheduling commitment
4. Conflicts between project professionals are internalized and may not involve the owner.

**Disadvantages:**

1. A design builder may provide reduced building features to protect profit margins
2. Involvement of the owner is generally limited to the early stages of a project
3. Hidden reductions in quality are possible when cost savings and design changes are determined by a design builder
4. The designer does not represent the owner's interest but is responsible instead to the contractor.

## 6.3 Engineer-Procure-Construct (EPC) Projects

These are configured in a manner very similar to DB projects. Most of the design and construction functions are performed or managed by one organization (Figure 14). This model, however, is used primarily for industrial projects that emphasize engineering design, as opposed to architectural design. The EPC projects typically have commissioning and maintenance phases included to allow for a plant to reach its designed operating capacity after acceptance.

**Advantages:**

1. The system has control over financial expenditures
2. There is better communication between the owner, designer, and the contractor

**Disadvantages:**

1. The system does not eliminate the need for an owner's representative
2. The designs may be unimaginative, emphasizing cost over quality
3. The post contract variations are difficult to bring about
4. The system is not suited for refurbishment work.

## 6.4 Design-Construction Management (CM) Contracts

The owner typically hires a CM organization, for a fee, to provide professional management services. Trade contractors contract directly with the owner on an individual basis and not through the construction manager, although the CM advises the owner on the formation and conduct of those contracts. The owner also contracts separately with a design concern (i.e., an architectural/engineering (A/E) firm) to obtain the design documents.

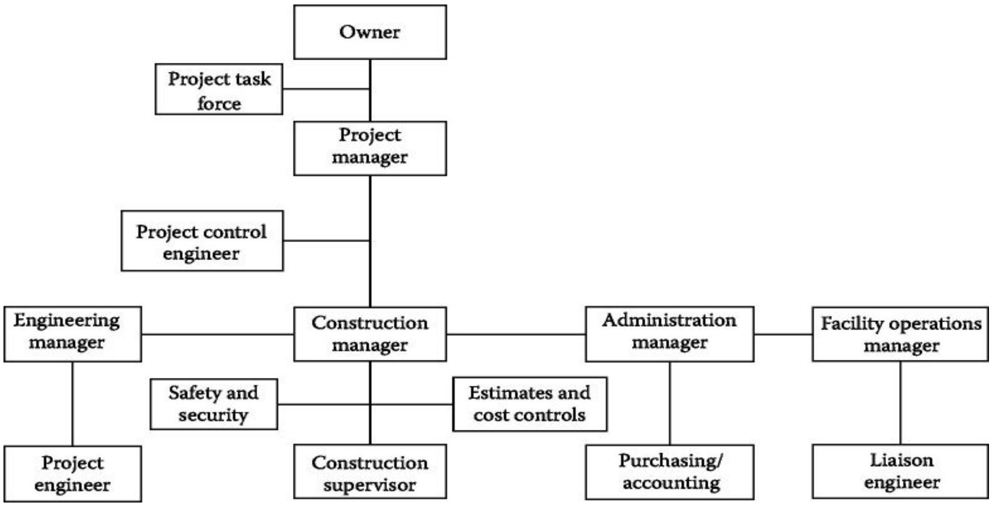


**FIGURE 14 Organization chart for an engineer-procure-construct (EPQ project).**

In some instances, the A/E firm may play the role of the CM. This form of contracting places a heavy responsibility on the owner to coordinate the work, as the trade contractors do not have contracts with each other and have no contractual obligation to cooperate (Figure 15).

**Advantages:**

1. The CM agent, with construction expertise, provides the owner with an agent in addition to the designer to supervise the project. This reduces the owner's management burden in large or complicated projects
2. The CM agent's project scheduling and capability to competitively fast-track some items may speed up the process and save money for the owner
3. The CM agent's cost estimating and construction expertise at the design phase assist in monitoring construction costs.

**Disadvantages:**

1. The CM agent is an added cost. The owner is at risk for final construction cost; actual construction costs are not known until construction is complete
2. Multiple prime contracts increase paperwork and administrative time and increase the potential for construction disputes and claims
3. The CM agent typically has less clout to resolve design or construction issues than a general contractor and serves only as a mediator.

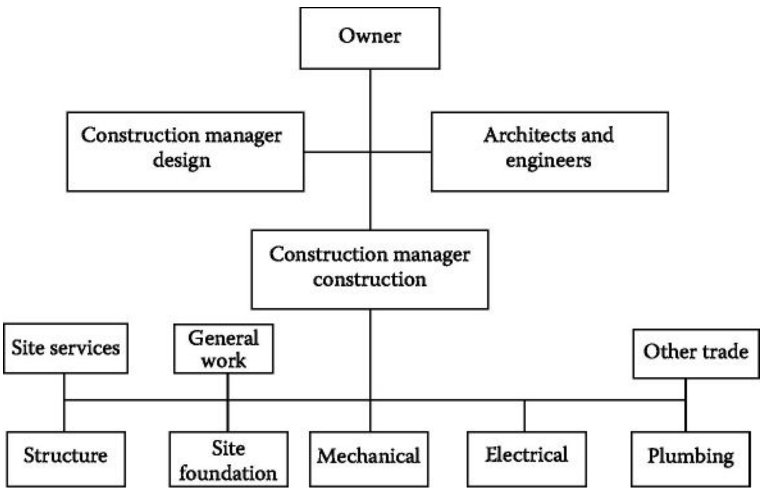


**FIGURE 15 Organization chart for a design CM contract.**

## 6.5 Design-Agency CM Contracts

In this type of contract the owner hires a design team to prepare project construction documents, and also hires a construction manager (CM) to oversee the construction phase of the project. This is often done on the basis of a lump-sum or fixed-price contract. The CM may act as an agent of the owner, contracting directly with all the trade contractors. The CM prepares bid packages that are priced competitively by the trade contractors, and reviews these bids to select the most appropriate ones (Figure 16).

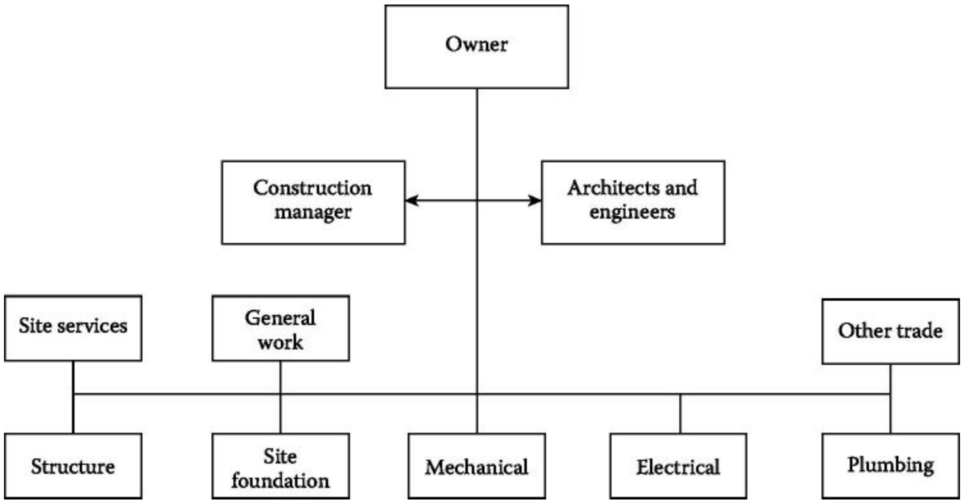


**FIGURE 16 Organization chart for a design-agency CM contract.**

**Advantages:**

1. Fewer management resources are needed
2. Participants' roles are clear and widely accepted
3. The process is well established and universally understood
4. This is a fixed-price contract based on complete documents with little room for change orders.

**Disadvantages:**

1. Contracts are awarded based on a low bid regardless of past performance
2. Construction starts after design work is complete and approved
3. Design quality may suffer from a lack of input from contractors) and sub(s)
4. The designers' fees may increase as change orders increase
5. Changes in the scope (i.e., design, unforeseen conditions, timeframe, etc.) will generate change orders.

## 6.6 CM-at-Risk Contracts

The construction manager in this type of contract assumes the risk of pricing and contracting directly with the respective trade contractors. In general, CM-type contracts are not as amenable to quality initiatives as DBB and DB contracts.

Construction Management at Risk (CM@Risk) is increasingly being used by the U.S. public sector. Like design-build, it facilitates improved quality through a selection process based on factors other than the low bid. A scoring system is used to consider the previous performance of a contractor, based on various criteria. It is not the cheapest method—it is best used where there is uncertainty, such as renovation projects where the current state of a facility or its infrastructure may not be entirely known. This uncertainty is reduced by having the CM involved in managing the design phases of a project, in the selection of sub or specialty contractors, and then assuming the risk for successful completion. Bidders tend to build in safety cushions for unforeseens, but a guaranteed maximum price (GMP) approach may be used to set a specific limit to the owner's project cost. Consequently, project budgets for CM@Risk are somewhat generous, resulting in less emphasis by contractors on cost reduction, and fewer compromises in the area of quality (Figure 17).

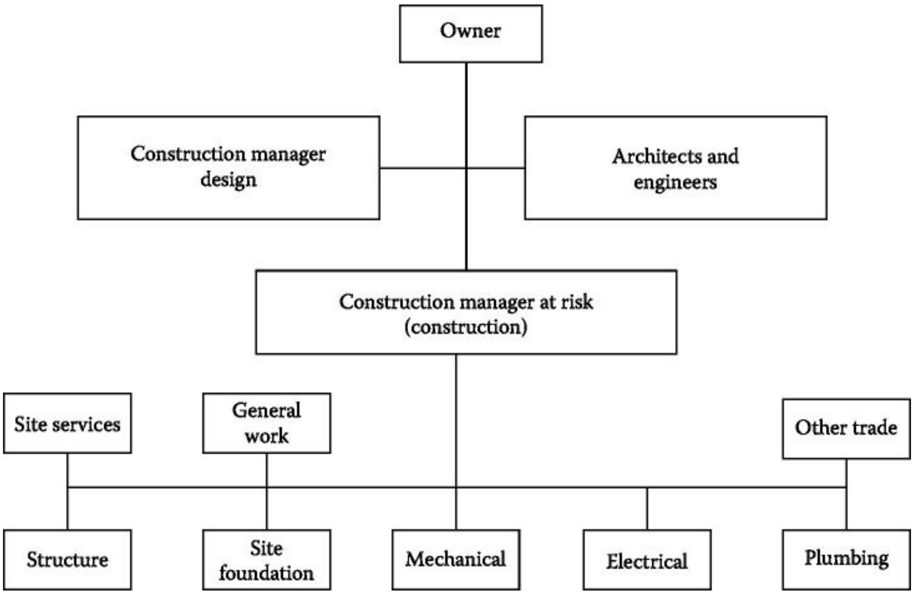


**FIGURE 17 Organization chart for a CM-at-risk contract.**

**Advantages:**

1. Early cost-commitment gives the owner project cost security
2. The at-risk entity is responsible for managing the construction process and has more influence over subcontractors
3. The CM contractor can reduce the owner's burden in the management of large or complicated projects
4. The CM contractor reviews projects for constructability, cost, and schedule, potentially reducing change orders and delays
5. Fast-tracking and multiple prime contracts may speed construction.

**Disadvantages:**

1. The management role of the CM contractor is an added cost
2. The CM contractor may provide reduced building features that are available with a bid approach, in order to protect the margin of profit
3. There is a potential conflict of interest with having one entity serve as both construction manager and contractor.

## 6.7 Fast-Track Construction

Fast-track construction is valuable in meeting accelerated schedules demanded by the owner. It allows a contractor to commence construction immediately after contract award, while a designer simultaneously completes the construction documents. It may be conducted with or without a design builder.

**Advantages:**

1. The most important advantage of the system is its conformance of the basic design.
2. The system also has better constructability compared to the other systems.
3. The system also requires demanding documentation and minimizes the cost of overruns.
4. The system increases productivity by speeding up the construction process.

**Disadvantages:**

1. The system can create misunderstanding between the owner, designer, and the contractor
2. The system is prone to an increased number of errors from the designer
3. To correct errors or to change to more advantageous designs requires more change orders than would be needed with standard construction scheduling
4. In the fast-track process, incomplete drawings and specifications are incrementally released for bidding, governmental review, and construction.

## 6.8 Partnering

Partnering is the formation of a project team to deliver a construction project; the team commits to open communications in a spirit of trust and works to accomplish mutual project goals. While the team members work supportively to meet mutual goals, they also focus on their individual goals. Yet, they recognize that their individual success is linked to the overall success of a project.

First-level partnering involves team formation for an individual project. On the other hand, second-level partnering involves members of a team that have worked together successfully on one or more projects and have come to recognize the benefits of a long-term relationship. Kubal (1994), points out that team members do not all have to be the same in order to have second-level partnering; the team may have a combination of participants from previous teams.

Partnering has resulted in projects that are far less reliant on litigation to ensure that project objectives are met. It significantly reduces the fragmentation that characterizes many construction projects, as a result of which the employees of the involved companies tend to work more on an individual level rather than an organizational level. The reduced reliance on legal resources often lowers project costs, to the benefit of both owners and design and construction providers.

The success of partnering activities has been linked to certain common factors:

1. Selecting a team based on competent member companies that can be mutually respected based on their respective track records.
2. Selecting a team with member companies whose top management will commit to a spirit of teamwork.
3. Conducting partnering sessions with an experienced facilitator who can work in a neutral capacity to conduct team-building exercises.
4. Clarification of project goals and performance requirements, and "buy-in" by the respective companies.
5. Operating procedures: communications, problem resolution, and documentation protocol.
6. Mutually agreed systems for measuring performance.

Project success is further enhanced by having employees of the involved companies view themselves as collaborating with each other as opposed to viewing their interaction as only a relationship between companies.

**Advantages:**

1. The completed construction is of a higher quality standard
2. Overall costs are lowered
3. Profit margins for participants are higher than in traditional approaches
4. There is less adversariness and legal costs are significantly reduced
5. Errors and omissions are reduced by improved communication during both the design and construction phases
6. There are fewer change orders.

**Disadvantages:**

1. Transactional exchanges between team members are guided by the construction contract while relational exchanges are not legally enforceable
2. Ongoing team-building sessions are needed to maintain the benefits of partnering
3. Unless all team members begin participation at the same time (at the preconstruction phase) they may not form a cohesive team
4. Partnering cannot work effectively if projects are planned with unrealistic schedules, inadequate budgets, or with constructability problems.

## 6.9 Relational Contracting/Lean Design and Construction

Howell (2000) describes lean construction as a new way to design and build capital facilities. Lean theory, principles, and techniques jointly provide the foundation for a new form of project management. It uses production management techniques to make significant improvements particularly on complex, uncertain, and quick projects. Lean methods have reduced office construction costs by 25% within 18 months and schematic design time from 11 to 2 weeks.

Lean construction departs significantly from current project management practice. Processes are actively controlled and metrics are used in planning system performance to assure reliable workflow and predict project outcomes. Performance is optimized at the project level. Whereas current project management approaches reduce total performance by attempting to optimize each activity, lean construction succeeds by optimizing at the project level, as opposed to the less effective current project management approaches, which reduce total performance by attempting to optimize each activity.

Lean applications in design and construction are continually evolving. The most successful applications have been observed with forms of contract that reward cooperation and collaboration between the parties that are actively involved in delivering design and construction. The Integrated Form of Agreement (IFOA) is one form of contract that has been successfully applied to lean construction.

Figure 18 represents one interpretation of lean project delivery, namely Integrated Project Delivery (IPD). The team comprises the GC/CM collaborating closely with designers and the primary subcontractors. The team members have relational contracts between them, as delineated by those entities encircled by the dotted line; these are described as "Single pact." The right-hand box (at-risk pool) "rescues" any individual firm that encounters financial difficulty; by the same token, team behavior is likely to leave a surplus in the account. This surplus is shared between the members of the integrated team.

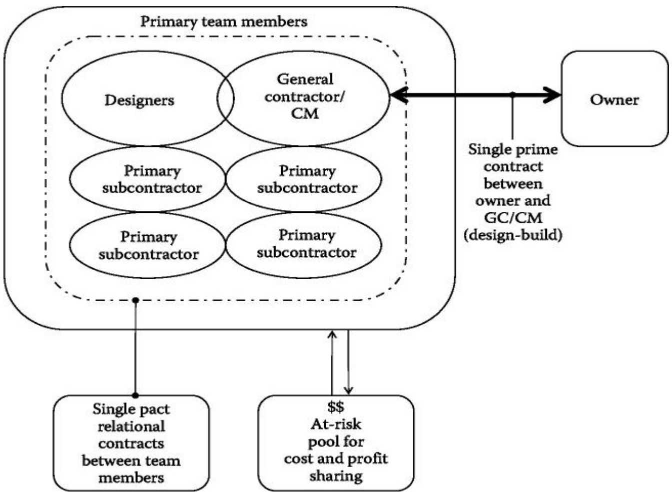


**FIGURE 18 A representation of Integrated Project Delivery (IPD).**

## 7. Forms of Contract

There are several categories of construction contracts that cover the spectrum of available approaches, all of which may be integrated with the foregoing construction delivery methods. Some categories of contract formats may be better suited to particular delivery methods, although the number of contract formats is almost infinite, just as there are no two projects exactly alike. The more frequently used formats are lump- sum contracting, GMP, GMP with cost-savings sharing, and cost-reimbursable contracts (cost-plus). The cost-plus compensation formats may include cost-plus with GMP, cost-plus with guaranteed maximum and incentive, and cost-plus with GMP and provision for escalation.

### 7.1 Fixed Lump-Sum Price

The contractor receives a fixed sum for completion of the contract. This fixed sum may be adjusted for such things as owner changes in the work, differing site conditions, suspensions or delays, defective specifications, and so on.

### 7.2 Guaranteed Maximum Price

The contractor provides cost estimates throughout the design process and, at some point prior to completion of the construction documents, submits a GMP proposal. The GMP proposal is based on a scope of work outlined in the preliminary design documents, and usually proposes that the contractor be reimbursed for the cost of the work, plus a predetermined fee with a maximum fee specified. Because of the incomplete nature of the design, contingencies and allowances are included in the GMP and the contractor is expected to build the job within the GMP limits, unless there is an owner-directed scope change.

### 7.3 Cost Plus a Fee

The contractor receives its actual "cost of the work plus a fee for overhead and profit." Definitions of cost (such as in AIA document Alli) include the contractor's direct jobsite costs. Agreement on cost definitions is essential to avoid disputes over allocation of items to reimbursable cost or to fee. Since an open "cost-plus" arrangement is in effect a blank check, cost controls, and audits are essential. Fees may be negotiated either as a fixed lump sum or as a percentage of the cost. The latter encourages the contractor to spend more to increase its fee.

### 7.4 Fixed Unit Prices

The contractor receives a fixed sum for each unit of work completed. Because the units are not fixed, contracts may provide for renegotiation of the unit price for substantial variations in unit quantities from estimated quantities.

### 7.5 Advantages and Disadvantages of Different Forms of Contracts

Lump-sum contracting is often based on definitive specifications and requires complete, detailed design. Construction efficiency and quality are maximized in direct proportion with the availability of design detail. The overall time frames required are longest, as separate design and construction contracts and phases are involved. Lump-sum, based on preliminary specifications and complete general specifications, is often used for "turnkey" projects such as plant construction. Time is saved by concurrent design and construction, and the single party responsibility inherent in this format promotes efficient project execution.

Cost-plus contracts are appropriate where the scope of work does not have to be clearly defined (e.g., in major revamping of existing facilities), where technology is not well-defined or needs to be confidential. Minimum time schedules are generally obtained, but the owner/client needs to provide extensive engineering supervision and cost-control. Cost-plus with GMP usually involves at least preliminary drawings and general specifications. Fast time schedules are possible at the expense of high contract prices, due to the contractor's risk exposure. Cost-plus with guaranteed maximum and incentive leads to fast schedules and higher prices than fixed-price contracts, but encourages the contractor to pursue savings as they are shared between both parties.

Cost-plus with a guaranteed maximum and provision for escalation is generally used for long time schedules, where prices may increase substantially, and project definition is preliminary. Tight owner cost control is needed. Time and materials contracts that are based on a general scope of work assure the contractor of a reasonable profit, reduce the scope definition/proposal time needed, but require extensive client supervision. Bonus/penalty, time, and completion clauses are used when timely completion is highly critical to the owner. The level of project definition provided greatly affects contract prices. The involved penalties impose high risk on the contractor, and quality is often reduced to meet time schedules. Bonus/penalty, operation, and performance contracts are typically used in process plant construction to guarantee successful plant operation.

Unit-price contracts (flat rate) are best used for repetitious/homogenous tasks such as highway building, or gas transmission piping. Work can proceed effectively even if the parties do not initially know the precise quantities of labor and materials required for the involved work. Unit-price contracts (sliding rate) are appropriate for the foregoing projects, but require extensive client field supervision to ensure that the involved quantities are properly monitored.

## 7.6 Strategies for Improving Construction Performance

Subsequent chapters address lean and productive practices to improve construction performance. These practices include a new paradigm for construction that includes a strategic management approach to focus the parties on optimizing performance at the project level, instead of seeking their own self-interest. These practices include the application of performance improvement and industrial engineering techniques, including the lean methods that have been successfully applied in the manufacturing sector.

The lean methods are based on a participative approach such as relational contracting and lean project delivery to improve the interaction between the members of the project team. Lean is the ultimate in collaboration and cooperation. In relational contracting, companies in the project team put the project first and gains and losses are shared.

# 8. Antivirus-built environment: Lessons from Covid-19 pandemic

COVID-19 affects physical health most directly and has alarming implications for emotional and social functioning, the coronavirus has proven that a disaster doesn't fight with a known opponent. The enemy can simply be invisible with devastating consequences (*Goniewicz et al., 2020; Pfefferbaum & North, 2020*). The real world is fragile, and this virus is frighteningly causing massive disruptions across the globe (*Budds, 2020; Saadat, Rawtani, & Hussain, 2020*). Moreover, the digital world is fragile regarding cyberattacks. This could be a teachable moment to apply lessons from the cybersecurity world to protect our built environment during the COVID-19 pandemic. The coronavirus is quickly spreading and causes significant damage, mimicking the spread of computer viruses within a network (*Kindervag, 2020*). In the digital world, it is common practice to design and incorporate solutions that can help overcome virus attacks; for every new generation, a new security layer is added to ensure the ever-mutating computer viruses do not harm the digital structure (Ahlefeldt, 2020). Could policymakers, planners, and architects inspired by the digital world learn from its cybersecurity to make our built environment more resistant to the virus? Could we design and build our cities to stop the virus from spreading? If so, could we install an antivirus-built environment ready to help in the protection from coronavirus or other pandemics?

Infectious disease has already transformed our places through architecture, design, and urban planning. Previously, many trends in architecture and urbanism that we see today were derived from similar measures taken before to ensure the health, hygiene, and comfort of urban residents. Our built environment has always exhibited the capacity to evolve after the crisis (*Chang, 2020; Dejtiar, 2020; Muggah & Ermacora, 2020*). This study encourages the search for suitable design ideas, trends, and planning theories to provide the required protection from virus attacks and continue to add more layers in the defense system of our built environment. To cope with this pandemic, professionals in architecture, urban planning sectors, and design agencies have already switched their focus to visualize the post-pandemic era. However, there is inadequate research conducted to imagine how the antivirus-built environment would look. To address this gap, this study reviews architecture and urban story developments from the past centuries. We then review research areas affected by the COVID-19 pan- demic and highlight their related questions. We then analyze the social distancing and quarantine as a design problem in the post-pandemic era. Subsequently, some lessons learned from the pandemic are presented to visualize and introduce the study's vision about the antivirus- built environment.

## 8.1 Historical background: dramatic change developments

During pandemics, the form has always followed the fear of infection, just as much as the function (*Ellin, 1999*). From interiors to city planning, our built environment is shaped by diseases. Previously, to minimize the risk of infectious diseases, people redesigned interior design, architecture, cities, and infrastructure. Considering historical events of the last two centuries, the architecture and urban story includes several developments.

### Urban renewal

In the 14th century, the bubonic plague motivated the fundamental urban improvements of the Renaissance. Cities cleared overcrowded living quarters, expanded their margins, developed early quarantine facilities, and opened large public spaces. In the 20th century, infectious disease was one of the drivers of urban renewal. Modernist architects saw design as a cure to the sickness of overcrowded cities, where tuberculosis, typhoid, polio, and Spanish flu breakouts encouraged urban planning, slum clearance, tenement reform, and waste management (*Chang, 2020; Lubell, 2020*).

## Sanitary reform

During the industrial era, cholera and typhoid influenced the sanitary reform movement. These epidemics contributed to developing water and sewage systems to fight the pathogens, eventually leading to a sanitary innovation and required the streets to be straighter, smoother, and wider to install underground pipe systems. Furthermore, the third plague pandemic in 1855 changed the design of everything from drainpipes to door thresholds and building foundations (*Budds, 2020; Klaus, 2020; Wainwright, 2020*).

## Building and housing reform

The wipe-clean esthetic of modernism can be partially attributed to tuberculosis. The modern architectural designs were inspired by an era of purity of form, strict geometries, modern materials, and a rejection of ornamentation. Modernist architects designed these curative environments as cleansed (physically and symbolically) from disease and pollution. Beyond their esthetic appeal, these features embodied modernist preoccupations with the healing effects of light, air, and nature. These buildings included large windows, balconies, flat surfaces that would not collect dust, and white paint, emphasizing the appearance of cleanliness (*Budds, 2020; Chang, 2020*). Against this background, the current health crisis should develop our built environment to increase the security layers that help to prevent the spread of infections and diseases. In this context, there are multiple areas of research needed regarding COVID-19.

## Research areas and questions

When the World Health Organization (WHO) declared the fast-spreading COVID-19 as a pandemic, citizens around the globe hastened to go home. This global pandemic significantly influenced our personal and professional lives and has a direct bearing upon the very foundations of urban planning and architecture theory and practice (*Allam & Jones, 2020; Haleem, Javaid, Vaishya, & Deshmukh, 2020; Saadat et al., 2020*). Consequently, the pandemic has led to questions of how architects and planners could present and install antivirus-related ideas or update the existing spaces, as well as at what stage can the pandemic affect our physical and built environment. To extend the scope of re- search needed from the academic community, Table 2 reviews certain required research areas affected by COVID-19 and highlights their related questions. Professional and extensive research is required on all levels and scales in these areas to prevent the virus from spreading. The answers to these questions could help in predicting the post-pandemic style and visualizing the required antivirus system.

**Table 2 Post-coronavirus architecture and urbanism: Research areas and questions**

Post-coronavirus architecture and urbanism: Research areas and questions.

| Scope | Research Areas | Research Questions |
|---|---|---|
| Post-pandemic urbanism | • Digital transformation and telecommuting<br>• Centralization and decentralization<br>• Density of cities<br>• Walking, cycling, and public transportation | • The COVID-19 crisis has changed the face of many of our cities and questioned how we should manage urban life in the wake of a pandemic. Would the pandemic inspire more urban improvements? Can we design cities that reduce infections? Would the post-pandemic era generate new urbanism based on social distancing? More specifically, could COVID-19 be a catalyst for decentralization and walkable cities? |
| Post-pandemic public spaces | • Design, use and perceptions<br>• Design and disease transmission<br>• Street design and furniture<br>• Shared facilities and services<br>• Flexibility and transformation | • There is no doubt about how COVID-19 will impact future public buildings and spaces. However, how long will these impact and reflection last for future? What about their furniture materials, shared facilities and services? What is the future of commercial buildings? Can air-conditioned shopping malls continue? Will the pandemic teach us new lessons to incorporate into our public buildings and spaces designs? |
| Post-pandemic housing | • Housing layout<br>• Space and density<br>• Shelter and safety<br>• Indoor air quality | • What is the future of our houses? Should they adapt to better accommodate workspaces? Should they be self-sufficient? Should our terraces, balconies, and roofs be planted? More specifically, could COVID-19 be a catalyst for healthy housing and sustainable buildings? |
| Post-pandemic office space | • Layout and design solutions<br>• Working and waiting spaces<br>• Shared facilities and services<br>• Density in offices<br>• Building heights | • What is the future of co-working spaces and open-plan offices? Could COVID-19 alter their design? Would they need new design criteria? What is the future of high-rise buildings? Can skyscrapers continue? What happens when nobody wants to use elevators? |
| Building and construction technology | • Modular construction<br>• Prefabricating standardized components<br>• Lightweight and adaptable structures<br>• Artificial intelligence | • What is the future of construction strategy? Could COVID-19 alter its techniques? Should we adopt a more modular construction strategy? If so, will the future witness more prefabricating and standardized components? Could the pandemic speed up the digitalization and automation of our cities? Will our smart devices control everything around us? |

## Social distancing and quarantine as a design problem

In the absence of a specific vaccine to the coronavirus, physical distancing and the lockdown of the population are among the most immediate and precautionary measures to be taken. The WHO introduced these measures, which were practiced at both institutional and individual levels to become a universal mainstream strategy (*Hishan, Ramakrishnan, Qureshi, Khan, & Al-Kumaim, 2020; Salama, 2020*).

## Potential transmission dynamics of COVID-19

Since most humans spend most of their daily lives inside the built environment, it is essential to understand the potential transmission dynamics of infection. As individuals move through the built environment, COVID-19 can be transmitted both by air and via direct and in- direct contact. Viral particles can be directly deposited on surfaces or suspended due to natural and mechanical airflow patterns, or other sources of turbulence in the indoor environment (*Cirrincione et al., 2020; Dietz et al., 2020; Horve et al., 2020*). The WHO has prescribed maintaining an inter-personal distance of 1.5 or 2 m (about 6 feet) to minimize the risk of infection. However, more recently published stu- dies support the hypothesis of virus transmission over 2 m from an infected person (*Bourouiba, 2020; Setti et al., 2020*). In addition, Oklahoma State University researchers simulated different environmental and movement conditions to see if a six-foot social distancing policy is enough. Their results indicate this policy is enough if the ambient air is static (*Oklahoma State University, 2020*). Other factors and wearing protective clothes affect the transmission dynamics of infection. However, WHO is continuously changing and updating all the mentioned distances based on the latest information and research conducted by professionals.

## Design problem and challenges

Based on the potential transmission dynamics of COVID-19 and the required measures, several competitions, conferences, and leagues have been cancelled or postponed. The coronavirus has motivated authorities to restrict access to most public spaces and large shopping areas. This pandemic could fundamentally change the way they operate in the future and requires further analysis (*Honey-Roses et al., 2020*). Architects, planners, and built environment professionals are keen to ex- amine many social and spatial implications to generate new patterns and configurations of use (*Paital, 2020; Salama, 2020*). Architectural and urban spaces, as they relate to infectious disease epidemics, are not only about quarantine based on immediate and precautionary measures but also refer to design and planning problems and challenges in all building types and urban spaces. The pandemic of COVID-19 has caused profound consequences that can be an opportunity to review individual and collective choices and priorities. Most architecture today shows evidence of how humans have responded to infectious diseases by redesigning our physical spaces. Thus, social distancing could change the design and planning process (Budds, 2020; Chang, 2020), specifically with the increased acceptance of distance learning, online shopping, and the cultural connection of online entertainment. The use of media for information sharing, and webinars for sharing knowledge and expertise have seen widespread adoption during the COVID19 pandemic (*Chick et al., 2020; Goniewicz et al., 2020*). Although new technologies can create additional difficulties, opportunities have emerged to apply innovative solutions to more smart and virtual world applications in the built environment. When we increasingly work from a remote location, learn and upgrade skills online and shop for necessities from e-commerce sites, we reduce the need of traditional physical spaces by virtual digital ones which can be accessed from smart devices (*Goniewicz et al., 2020; Hishan et al., 2020; Papu & Pal, 2020*). According to the affected lifestyles, the increased reliance on digital channels in the built environment may endure long after the pandemic and affect in every design and urban aspects. Humanity is facing a global crisis, perhaps the greatest of our generation. Many measures adopted during the emergency will become part of daily life, changing habits, and behaviors, they may be a positive or negative intervention in architecture and urban planning approaches.

While there are many potential impacts of COVID-19 on built environment, our focus in the following points is on how post-architecture may change. Although social distancing and quarantine measures are extensively adopted as the first preventive measure, other factors increase the risk of contracting the virus, as discussed below.

Population density. In our current health crisis, certain densely populated cities have proved to be particularly vulnerable to the risk of infection (*Chang, 2020*).

Household size. A big household, large, or extended families will have a higher chance to bring the virus home (*Saadat et al., 2020*). This will need special consideration in designing solutions to prevent infection.

Social distancing level. Working from home might reduce social contact but is only available to some people focused on jobs linked to a higher socioeconomic status. Moreover, stay-at-home regulations would be more than a challenge for those who live in smaller and crowded houses or without outside spaces (*Saadat et al., 2020*).

Shared facilities. Shared housing includes a broad range of settings with special considerations. People living and working in this type of building might have challenges with social distancing to prevent the spread of COVID-19 (CDC, 2020).

Housing characteristics. With a stay-at-home attitude essential to the COVID-19 response, housing characteristics take on added importance in people's lives (*Schellenberg & Fonberg, 2020*). Extended time in- doors could raise various challenges in the design of post-pandemic housing. Because we are forced to stay and work from home, post- pandemic houses and office spaces will witness a great transformation because we will be more aware of the functionality of our homes and workspaces in an interestingly new approach. Some of these transformations are reviewed in the following sections.

### Post-pandemic housing

The pandemic has brought a greater sense of appreciation for our homes. People need houses that can effectively provide social isolation and offer protection from viruses and infections. The expectation is that even after the quarantine period, more people will work from home. Consequently, the future of home design might change (*Dejtiar, 2020; Kashdan, 2020; Priday, 2020*). Several studies have reported a direct association between crowding and adverse health outcomes. The WHO suggested the characteristics of healthy housing. High density could lead to unhygienic conditions and the spread of several communicable diseases. Crowding increases the risk of volatile infections and droplet- transmitted infections (*Capolongo, Rebecchi, Buffoli, Letizia, & Carlo, 2020; World Health Organization, 1988*). If possible, the current pan- demic makes a strong case for completely detached housing with a reasonable amount of surrounding garden space, enhancing better facilities for social distancing and producing food, and the healing effects of light, air, and nature. Perhaps quarantine is the best time to get to know more about indoor gardens, even in the case of multi-story buildings (*Makhno, 2020; Wainwright, 2020*). For multi-story buildings, contact with other residents in shared areas is unavoidable. The future should, therefore, focus on the touchless experience from the front door to the apartment door itself (*Kashdan, 2020; Priday, 2020*).

Regarding layout and design solutions, post-pandemic housing might introduce more partitions between departments and could be the end of open-plan spaces. The building might have wider corridors and doorways, and many more staircases, leading to changes in the building code and design strategies. Ensuring flexible and adaptable spaces for all users can make housing more sustainable, able to adapt to changing needs and to changing lifestyles (*Capolongo et al., 2020; Wainwright, 2020*).

Social distancing and lockdown reflections with the links to the variables under research are illustrated in Figure 19.

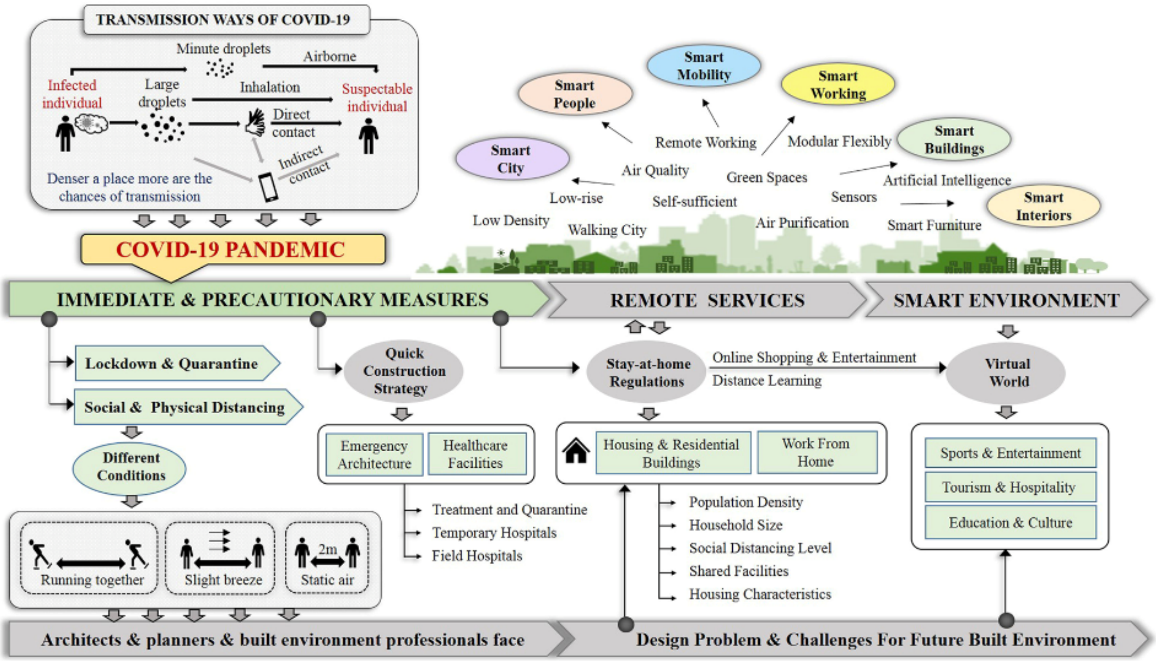


**FIGURE 19 Social distancing and lockdown reflections and their links to the variables under research.**

## Post-pandemic office space

Remote working consists of a relatively new mode of alternative work arrangements developed in the 1970s. Several firms have been adapting their measures as the spread of Covid-19 increases (*Belzunegui-Eraso & Erro-Garcés, 2020; Papu & Pal, 2020*). Even firms that were resistant to the concept of remote working have been forced to allow working from home. However, working from home all the time is not for everyone; many will want to return to their physical offices. As the pandemic continues or remote working becomes the new norm, office space might have to be altered to create greater spacing and fewer seating options (*Marr, 2020; Molla, 2020*). Based on this trans- formation, the density in offices might probably change and firms will not need more space because of work from home policies.

Consequently, high-rise buildings would become more expensive to build and become less efficient. Depending on how productive remote work proves to be in this pandemic, it is hastening the shift from structured office environments to more flexible, virtual, and home-based work arrangements, which could mean a reversal of the open-office trend and the search for better other natural ventilation and healthy design options (*Alter, 2020; Muggah & Ermacora, 2020*). Regarding cleaning policies, certain firms could even use ultraviolet germicidal irradiation to deeply disinfect offices at night or meeting rooms between uses; a practice that is increasingly common in hospitals to combat the spread of infection (*Beggs et al., 2000; Kovach et al., 2017; Molla, 2020*).

## An opportunity to reset and reshape our built environment

While it is uncertain how much change will follow COVID-19, mechanisms increasing its spread will not be forgotten or ignored (*Priday, 2020*). The pandemic has highlighted the lack of how we manage our built environment and presented certain lessons from this forced experiment. In this context, how should architects, planners, and policymakers react and learn? Beyond helping to design medical spaces limiting the spread of infections (*Acuto, 2020; Betsky, 2020*), the pandemic will allow them to reset and reshape our built environment. However, the time to reset and reshape our built environment is now, and not after the next pandemic. This study analyzes the lessons learned based on two approaches, namely, look step back to nature and look step forward to advanced technology.

### Look step back to nature

A key lesson that we are going to learn is the requirement to return to nature with its healing effects. Although the situation is still unfolding, the COVID-19 pandemic has already highlighted the importance of certain design concepts and reassessed fundamental assumptions in urban and architecture approaches.

### Urban approaches

To accommodate work from home situations, we could even reexamine old urban typologies. Many urban approaches might increase the protection and defense system of our cities and avoid high density and overcrowding. Policymakers and planners should use the current crisis to review planning theories and, based on the results, they should take a step back in searching about how past cities are structured.

**Expanding horizontally.** During a pandemic, the human proximity of heavily populated cities poses further risks. The larger the popula- tion, the higher the concentration of COVID-19 in cities. Regarding the impact of social distancing, planners and architects might design according to expanding horizontally approaches with more available open spaces, which could be essential to prevent the spread of infections and diseases (Liu, 2020; Novakovic, 2020).

**Fewer density cities.** Because social distancing measures are essential to the containment effort, some have blamed the density of cities for the rapid spread of the infection and considered suburbs to be the safest places. Urbanization might take a step back to enhance villages and city suburbs, particularly with the increased acceptance of digital transformation (*Makhno, 2020; Nicola et al., 2020; Wainwright, 2020*). However, the impacts of higher density on social interactions and sustainability are still controversial issues (*Mousavinia, Pourdeihimi, & Madani, 2019*).

**Decentralization**. The pandemic highlights the importance of distributing smaller units such as health facilities, schools, and services across more of the urban tissue and strengthening local centers (Alter, 2020; Wainwright, 2020). As increased e-commerce models, the shopping malls may eventually lose their aspirational value, we would have to remodel traditional market in mixed use neighborhoods (Papu & Pal, 2020). In addition, the decentralized network of smaller green spaces will make it easier for residents to breathe nature that has important physical and mental health benefits (Velarde, Fry, & Tveit, 2007). Decentralization approach could probably encourage horizontal expansion, requiring a review of planning theories to maintain sustainable development and adequate city planning (*Madanipour, 2001; Taylor, 2000*).

**Urban farming.** The notion of a self-sufficient community is the answer to protect the environment and ecological systems (*Ali, Dom, & Sahrum, 2012; Martinez et al., 2010; Priday, 2020; Tait, 2003*). It is urgent to rethink how land is used with landscapes and urban farming integrated approaches (Proksch, 2017). Urban farming has been recently growing, strengthening self-sustaining communities to become more resilient to the epidemic. Farming could improve food security and nutrition, reduce climate change impacts, and lower stress. In this context, vertical and urban gardens should flourish (*Ahlefeldt, 2020; Chandran, 2020; Kashdan, 2020; Muggah and Ermacora, 2020*). Urban farming integrated approaches have been implemented using the latest designs and technologies with other architectural approaches (*Dmitriy & Alevtina, 2019*).

**Fewer cars, more cycling, and walking**. One of the key lessons that we are going to learn is having a network of cycling and walkable streets. Walking, as a primary mode of transportation and physical activity, has proven both environmentally friendly and beneficial for residents' physical and mental health (*Dreessen, 2020; Zhou, He, Cai, Wang, & Su, 2019*). In the fight against infection and maintaining social distancing, cities should offer safer paths and small roads for walking and micro-mobility than depending only on mass public transportation. While considered a good environmental solution to re- duce pollution, public transportation is not ideal during a pandemic as it might contribute to the spread of diseases among users (*Campisi, Acampa, Marino, & Tesoriere, 2020; Constable, 2020; Gonzalez, 2020; Musselwhite, Avineri, &*

*Susilo, 2020*). The pandemic has emphasized that efficient multi-modal transport is more robust and thus essential to sustainable growth. No single mode of transport is in the long run superior (*Capolongo et al., 2020; Hishan et al., 2020*). Streets might need to be re-designed to meet multi-modal transport needs, which succeed in transforming streets to become healthier, safer, greener, and more livable (*Honey-Roses et al., 2020*).

### Architecture approaches

Previously, many architectural approaches were related and increased the healthy spaces of our buildings and enhanced sustainability.

**Self-sufficient strategies**. In future, a high priority will be placed on self-sufficient buildings and lifestyles (*Ali et al., 2012; Greer, 2009; Priday, 2020*). In addition to all the energy-efficient strategies with heating and cooling systems, architects might inspire additional methods of thinking concerning water supply and food production.

**Refocusing on green spaces**. We require physical interaction with living plants for our mental health, and to grow what we eat to reduce risk, specifically during self-isolation (*Constable, 2020; Makhno, 2020*). Consequently, planting our gardens, terraces, and implementing green roof systems have multiple advantages for sustainability (*Hui, 2011; Specht et al., 2014; Thomaier et al., 2015*) and can solve most of the self-isolation problems. The challenge for the roofs is to consider them as the buildings' fifth façade to be the place of green roofs. However, during the design process, green roofs designed for food production might require additional calculations and requirements (*Abd-Elhafeez, ELmokadem, Megahed, & El-Gheznawy, 2016; EL-Gheznawy, 2016*).

**Low-rise buildings.** High-rise buildings were designed to organize as many people as possible in one place. During a pandemic, it is necessary to reduce contact with everything in multi-story buildings such as elevators, elevator buttons, door handles, and surfaces (*Capolongo et al., 2020; Makhno, 2020*). This new fear of infection and fear of being trapped in the elevator should take future consideration in post-pan- demic architecture with other psychosocial problems.

Better air quality. After forced self-isolation and spending more time indoors, an approach to improving health through strategies such as greater natural light, improved ventilation, fewer toxic substances, and incorporating plants and other natural materials is necessary (*Constable, 2020; Lubell, 2020*). In this context, it is critical to design buildings with skylights, large windows, rooftop terraces, balconies, and courtyards to avoid sick-building syndrome and enhance air quality (*Guy & Farmer, 2001; Roaf, Crichton, & Nicol, 2010*).

### Look step forward to advanced technology

To receive the maximum benefits from the previous approaches, the antivirus-enabled paradigm requires advanced technology in the construction sector and a tool to fasten the digital transformation. This approach requires using techniques outside the mainstream to secure our built environment by running alternatives, exploring, and inspiring new ways of constructing more sustainable and safe buildings.

### Construction strategy

The post-pandemic emphasizes the importance of look step forward

of the innovations in construction techniques that speed the creation of emergency architecture. The COVID-19 pandemic represents an unprecedented challenge for healthcare systems internationally. Medical facilities and their human resources are usually overwhelmed (*Robbins et al., 2020; Scarfone et al., 2011*). The sheer scale of the pandemic puts enormous stress, most countries built field and temporary hospitals in a matter of a few weeks or reused other building types and spaces to add thousands of beds. Table 2 reviews the most construction strategies used in constructed additional healthcare systems to prevent further COVID-19 infection.

**Modular construction.** Increasingly popular before COVID-19, the modular construction strategy is effective to face pandemics or natural disasters and to create less expensive and more quickly constructed buildings (Smith & Quale, 2017). It is important for meeting health services' diverse requirements with prefabricated standardized com- ponents. These components could help buildings adapt to requirements or enlarge their spaces for treatment and quarantine (*Hatcher, 2020*).

**Adaptive reuse.** This strategy is a sensitive and sustainable approach to create emergency facilities. During a pandemic, sports facilities, parking lots, and other buildings are converted into medical facilities and temporary hospitals. There will be a requirement for more efficient, effective, and flexible reuse plans for future crises (*Lubell, 2020*). This strategy is beneficial when integrated with other advanced technologies in the construction sector.

**Lightweight and adaptable structures**. When responding to the pandemic, lightweight and adaptable structures are often preferable for their speed and portability. Designers are developing and assembling these temporary structures to create field hospitals that can be easily transported and erected for COVID-19 patients (*Constable, 2020; Lubell, 2020*).

**Hygienic building materials.** There will be a special effort to consider and think about every possible place within the built environment touched by people and the possibility of that being a source of infections. Like the modernists who rejected ornaments in service of hygiene, contemporary designers are likely to use hygienic and anti- bacterial materials that can be easily sanitized (*Kashdan, 2020; Molla, 2020*). Post-pandemic architecture might apply more cleaning strategies based on new technologies. For applying a strategy based on nanotechnology, we should consider other potential risks associated with nanomaterials (*Megahed, 2013*).

## Digital transformation

The global pandemic has forced us into an entirely new world and has increased digital transformation in all our activities. After the crisis, we will have entered a new digital normal. In a few months, the pan- demic has offered virtual and augmented reality alternatives, which are expected to continuously increase (*Gracy, 2020; Muggah & Ermacora, 2020*).

**Ability to work from home.** As a lesson learned, this pandemic brought to light the possible reduction of air pollutant emissions by increasing expand remote working. During the quarantine, most people have been forced to work from home (*Nakada & Urban, 2020*). More consideration will be given to the arrangement of the workplace at home. The spatial organization will change. It will be a separate room with large windows, blackout curtains, and comfortable furniture. It will be technically equipped, and sound insulated (*Allam & Jones, 2020; Capolongo et al., 2020*). While working from home is a benefit many employees value and reduces pollution, the long-term impact is unclear and requires further investigation.

**Artificial intelligence and touchless technologies.** Automation, voice technology, and facial recognition-based in artificial intelligence could influence post-pandemic architecture. With 80 % of infectious diseases transmitted by touching polluted surfaces, touchless technology could become a new interface and remove the requirement for physically pushing or touching a surface. Post-pandemic principles search for more contactless pathways, such as lifts being called from a smartphone, avoiding the need to press any buttons, and doors to open automatically (*Molla, 2020; Wainwright, 2020*). These technologies could include other programs to both control space temperature and automatically clean it to kill harmful organisms, viruses, and bacteria. Although there is an added cost, it might be an amenity that will gain popularity to be integrated into future buildings (*Kashdan, 2020; Makhno, 2020*).

## Antivirus-built environment

One positive impact of the current pandemic is the time it offers to the built environment professionals to reflect on past events and learn what can be improved for future responses (Goniewicz et al., 2020). Although pandemics have long been catastrophic, they have forced architecture and city planning to cope with it. Covid-19 might have similar effects on architecture and urban planning developments (*Budds, 2020; Chang, 2020; Saadat et al., 2020*). Life after the pan- demic will never be the same; values, lives, and habits will change, and our architecture will change under that influence. In all these circumstances, we might enter a completely post-pandemic style in which form follows fear of infection. Cities are currently being evaluated to the extreme with the pandemic and multiple questions are arising in terms of how cities are planned and managed. Its impact is showing the extent to which each city can function, or not, especially during times of crisis (*Lubell, 2020; Wahba & Vapaavuori, 2020*). Our built environment is not designed or built to effectively help limit the effects of pandemics, such as the COVID-19 pandemic. However, we are learning fast and there are already lessons worth learning and remembering. The pandemic will not last forever, but our response to it will shape our future built environment (*Ahlefeldt, 2020; Novakovic, 2020*).

The significance of adding human health as one of the sustainability development goals can be seen through the current pandemic. From a conceptual perspective, adding human health as the fourth pillar to the overall definition of sustainability is a logical step (*Hakovirta & Denuwara, 2020*). Many architecture and urban approaches might increase the protection of our cities and avoid overcrowding. In normal times, there might be many attributes attempted by the built environment to achieve sustainability. The pandemic's influence in the densest areas raises questions about sustainable development and fundamental assumptions of past theories. However, the future is still unclear; perhaps we hope to see a shift towards a greener, smarter, and a more sustainable built environment. Alternatively, distance communication and digital transformation could change our long-term habits and dramatically cut traffic and pollution. What if we harnessed telecommuting and digital city strategy as a way of social distancing and to help employees and citizens achieve work-life balance? Based on the feasibility of working continuing remotely after the pandemic passes, our cities might require fewer spaces for highways and parking lots. In this case, we could recover these spaces for use as safe cycling and walking networks. It sounds utopic but this vision might encourage people to take their bikes to work and give more space to pedestrians (*Gonzalez, 2020; Muggah & Ermacora, 2020*). Post-pandemic design and planning strategies must reflect this change. The right design and planning strategies now could help to position our built environment in the post-pandemic era. However, there are many other social effects beyond the pandemic; however, the long-term impact is unclear, requiring further studies. Let us hope we do not encounter this scenario; however, if it comes again, at least we can understand the risks and be better prepared in the prevention and quickly react in mitigation.

As shown from the lessons and the complexity of the pandemic, it is no longer safe to solely rely on a strategy to protect our architecture and urbanism. Instead, we must install an antivirus-built environment that incorporates a multi-layered approach of protection into its defense system. Architects and planners should design our built environment such as to stop the virus from spreading by creating an antivirus-enabled paradigm. This paradigm must improve new tools, options, and strategies that are more flexible, holistic, and responsive to better ad- dress the pandemic response at all levels and scales from interior design to city planning. Based on the lessons learned from this crisis, Fig. 20 shows the proposed vision about how nature and advanced technology approaches help in visualizing antivirus-built environments to stop the virus from spreading. However, selecting the best antivirus strategy depends on many factors, posing new challenges to choose that could be used or planned as long-term reforms. We must be proactive, not reactive, and continue to update this antivirus-enabled paradigm and install new approaches within its framework. Many questions still require further multidisciplinary studies. The proposed vision in this study does not have an expiration date, when the Covid-19 pandemic ended, most healthy architecture and urban approaches could be applicable to the pandemics to come. We could imagine all housing buildings as self-sufficient, independent and healthy neighborhoods and making smart use of the available technologies. It is crucial to make urban areas more resilient to emergencies response, to face epidemics and other probable future emergencies of every kind.

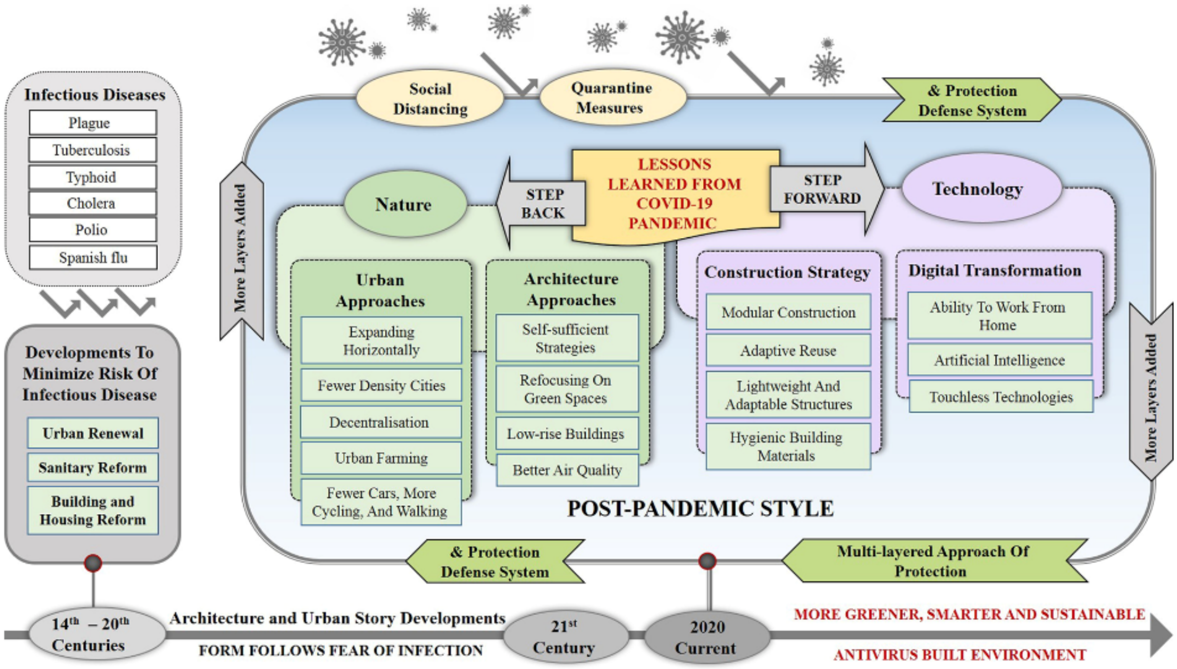


**FIGURE 20 Vision of the future of antivirus built environment**

In the face of the COVID-19 pandemic, the construction industry has been forced to confront numerous challenges and adapt to rapidly changing circumstances. The pandemic has not only exposed vulnerabilities in the way we design, build, and manage our built environment, but it has also helped us predict what post-pandemic architecture and urbanism might look like. Although a complete overhaul of our architectural and urban planning practices is not feasible, the current situation and emergency measures have prompted a reevaluation of our design strategies and planning theories. By effectively utilizing healthy design and planning strategies, we can better address pandemics and create a less polluted and more sustainable architecture and urbanism in general.

As we continue to grapple with the ongoing threat of infectious diseases, the concept of the antivirus-built environment has gained traction as a potential solution to minimize the spread of pathogens and promote public health. By integrating design, construction, and operational principles that prioritize hygiene, air quality, and occupant well-being, the antivirus-built environment seeks to create spaces that actively contribute to reducing the risk of disease transmission. The global pandemic has highlighted the limitations of our built environment management, but it has also provided us with valuable lessons and a unique opportunity to gain experience and adapt.

However, the post-pandemic era will present multiple challenges that require a better understanding of COVID-19 and its socioeconomic effects on society. The future remains uncertain, and further multidisciplinary studies are needed. Despite the uncertainties, the pandemic has increased the need for policymakers, planners, and architects to think more out of the box, reshaping our physical spaces and resetting the existing built environment or developing more ideas to face future virus attacks. These changes offer a glimpse of how our cities could change for the better or worse in the long term. This study aims to explore the importance of incorporating post-pandemic requirements into construction management principles and how these changes can contribute to a more resilient, sustainable, and prosperous future for the construction industry and the communities it serves.

## 8.2 Integrating post-pandemic considerations into modern Construction Management: a focus on Lean Construction and Building Information Modeling (BIM).

The COVID-19 pandemic has had an unprecedented impact on the global economy and various industries, with the construction sector being no exception. As countries worldwide grapple with the pandemic's effects, construction professionals must adapt their practices to meet new challenges and requirements that have arisen. This article aims to discuss the importance of integrating post-pandemic considerations into construction management principles, focusing on Lean Construction and Building Information Modeling (BIM) approaches. The target audience is master's students in construction management, and the article includes European examples and expert opinions from professionals in the field.

The construction industry plays a vital role in the global economy, providing essential infrastructure and supporting the growth and development of communities. However, the sector has long faced issues such as low productivity, inefficiencies, and a lack of standardization. The COVID-19 pandemic has only exacerbated these challenges, necessitating a shift in construction management practices to ensure the industry's resilience and continued growth.

During the pandemic, construction projects across Europe faced various difficulties, including project delays, supply chain disruptions, labor shortages, and increased health and safety requirements. These challenges have exposed vulnerabilities in traditional construction management practices and highlighted the need for new approaches that can better address the evolving demands of a post-pandemic world.

Lean Construction and Building Information Modeling (BIM) are two principles that have gained significant attention in recent years for their potential to improve construction management practices. Lean Construction is an approach that seeks to minimize waste and maximize value through continuous improvement, collaboration, and optimization of resources. Building Information Modeling (BIM) is a digital representation of a construction project's physical and functional characteristics, allowing for better collaboration, improved decision-making, and enhanced project management throughout the project's lifecycle.

By focusing on these two principles, this section aims to provide master's students in construction management with a comprehensive understanding of how Lean Construction and BIM can be adapted to address post-pandemic requirements. Through an examination of European examples and expert opinions, the article will highlight the benefits of incorporating post-pandemic considerations into construction management practices and offer insights into the future of the industry.

### Lean Construction and Building Information Modeling (BIM) Principles

Lean Construction and Building Information Modeling (BIM) have emerged as innovative and effective construction management principles that can address the challenges faced by the industry. Both approaches offer unique benefits and can be adapted to meet the new requirements presented by the post-pandemic era. In this section, we will explore the fundamentals of Lean Construction and BIM, as well as their relevance to construction management students.

### Lean Construction Principles

Lean Construction is an approach that has its roots in the Toyota Production System and the principles of Lean Manufacturing. It seeks to minimize waste and maximize value in construction processes through continuous improvement, collaboration, and optimization of resources. Lean Construction involves the application of various tools and techniques that aim to streamline processes, reduce inefficiencies, and enhance overall project performance.

Some key principles of Lean Construction include:

- Focus on value: Lean Construction emphasizes the importance of understanding and delivering value to the customer or end-user. By focusing on value, construction managers can prioritize activities and resources that contribute to the desired project outcomes.
- Eliminate waste: Lean Construction aims to minimize waste in all its forms, including wasted time, materials, and effort. By identifying and eliminating waste, construction managers can improve project efficiency and reduce costs.
- Continuous improvement: Lean Construction promotes a culture of continuous improvement, where project teams actively seek opportunities to enhance processes, eliminate waste, and maximize value.
- Collaboration and communication: Lean Construction encourages collaboration and communication among project stakeholders, fostering a team-based approach to problem-solving and decision-making.
- Process optimization: Lean Construction seeks to optimize construction processes by breaking them down into smaller, manageable tasks and identifying opportunities for improvement.
- For construction management students, understanding Lean Construction principles can provide valuable insights into how to improve project performance, reduce inefficiencies, and deliver value to clients in a post-pandemic world.

### Building Information Modeling (BIM) Principles

Building Information Modeling (BIM) is a digital representation of a construction project's physical and functional characteristics. BIM enables better collaboration, improved decision-making, and enhanced project management throughout the project's lifecycle. BIM is not just a 3D model; it incorporates various dimensions of information, such as time (4D), cost (5D), and sustainability (6D), that can be used to inform project planning, design, construction, and facility management.

Some key principles of BIM include:

- Collaboration: BIM promotes collaboration among project stakeholders by providing a shared digital platform where everyone can access and contribute to the project information.
- Visualization: BIM allows for the creation of detailed 3D models that can be used to visualize and communicate project designs, helping stakeholders understand and make informed decisions about the project.
- Data management: BIM enables the efficient management of project data, making it easier to track, analyze, and update information throughout the project lifecycle.
- Integration: BIM facilitates the integration of various project components, such as architectural, structural, and mechanical systems, enabling a more comprehensive and coordinated approach to design and construction.
- Lifecycle management: BIM supports the management of the entire project lifecycle, from planning and design to construction and facility management, providing a more holistic view of the project and its ongoing requirements.

For construction management students, understanding BIM principles can equip them with the knowledge and skills needed to effectively manage construction projects in a digital age, where collaboration, data-driven decision-making, and integrated processes are increasingly important.

## 8.3 Lean Construction and BIM Synergy

Lean Construction and BIM share several common principles and objectives, making them complementary approaches that can be combined to optimize construction management practices. Both Lean Construction and BIM focus on value, collaboration, continuous improvement, and process optimization, offering synergistic benefits when implemented together.

Integrating Lean Construction and BIM can lead to the following advantages:

1. Enhanced communication and collaboration: Combining Lean Construction's emphasis on teamwork and BIM's shared digital platform facilitates better communication and collaboration among project stakeholders. This increased collaboration can lead to improved decision-making and faster problem resolution, ultimately contributing to more efficient and successful projects.
2. Streamlined processes and reduced waste: The process optimization and waste reduction principles of Lean Construction can be further enhanced by BIM's data management and visualization capabilities. By integrating these approaches, construction managers can identify and eliminate waste more effectively and streamline processes across the entire project lifecycle.
3. Improved project planning and scheduling: BIM's ability to incorporate time (4D) and cost (5D) information into project models enables more accurate and efficient project planning and scheduling. This, combined with Lean Construction's focus on continuous improvement and value delivery, can lead to more predictable project outcomes and better resource utilization.
4. Enhanced risk management: Integrating Lean Construction and BIM allows construction managers to identify, assess, and mitigate potential risks more effectively. BIM's visualization and data management capabilities, combined with Lean Construction's focus on collaboration and problem-solving, can help project teams address risks proactively and develop more robust contingency plans.
5. Sustainable construction practices: Both Lean Construction and BIM encourage sustainable construction practices by promoting resource optimization, waste reduction, and lifecycle management. BIM's ability to incorporate sustainability (6D) information into project models can support Lean Construction's efforts to minimize environmental impacts and create more sustainable built environments.
6. For construction management students, understanding the synergy between Lean Construction and BIM and how these approaches can be integrated to address post-pandemic requirements is essential for their future careers. As the construction industry adapts to new challenges and regulations, professionals who can effectively apply Lean Construction and BIM principles will be well-positioned to contribute to more resilient, efficient, and sustainable projects.

In conclusion, Lean Construction and Building Information Modeling (BIM) principles offer innovative and effective solutions for addressing the challenges faced by the construction industry in a post-pandemic world. By understanding and integrating these principles, construction management students can develop the skills and knowledge needed to improve project performance, enhance collaboration, and contribute to a more resilient and sustainable built environment. As the construction industry continues to evolve in response to new requirements and regulations, professionals who can effectively apply Lean Construction and BIM principles will be well-equipped to lead the way towards a more efficient, collaborative, and successful future.

## 8.4 Incorporating Post-Pandemic Requirements into Lean Construction and BIM

The COVID-19 pandemic has brought about unprecedented challenges for the construction industry, such as supply chain disruptions, labor shortages, and increased health and safety regulations. To adapt to the post-pandemic era, construction managers need to integrate post-pandemic requirements into Lean Construction and BIM principles. In this section, we will explore how construction managers can integrate Lean Construction and BIM principles with post-pandemic requirements.

### Lean Construction

Lean Construction principles can be adapted to meet the new requirements of the post-pandemic era by emphasizing the importance of risk management, flexibility, and continuous improvement. Construction managers can integrate post-pandemic requirements into Lean Construction by implementing the following strategies:

- Improve supply chain management: To mitigate the risk of supply chain disruptions caused by the pandemic, construction managers can apply Lean Construction principles to optimize supply chain management. For example, they can collaborate with suppliers to reduce lead times, optimize inventory management, and reduce waste.
- Enhance flexibility: To adapt to the uncertainties brought about by the pandemic, construction managers can apply Lean Construction principles to enhance project flexibility. For example, they can use modular construction methods and prefabrication to facilitate rapid adaptation to changing project requirements.
- Foster a culture of continuous improvement: To adapt to the challenges posed by the pandemic, construction managers can apply Lean Construction principles to encourage a culture of continuous improvement. For example, they can use data analytics to identify areas for improvement in construction processes, reduce waste, and enhance project performance.
- Emphasize health and safety: The pandemic has highlighted the importance of health and safety in construction projects. Construction managers can apply Lean Construction principles to enhance health and safety by implementing measures such as temperature checks, social distancing, and enhanced sanitation.

### Building Information Modeling (BIM)

BIM can be integrated with post-pandemic requirements to enhance communication, collaboration, and data-driven decision-making. Construction managers can apply BIM principles to meet post-pandemic requirements by implementing the following strategies:

- Enable remote collaboration: The pandemic has emphasized the need for remote collaboration in construction projects. Construction managers can apply BIM principles to enable remote collaboration by using virtual platforms to share project information, facilitate virtual meetings, and enable remote decision-making.
- Enhance health and safety: The pandemic has also highlighted the importance of health and safety in construction projects. Construction managers can apply BIM principles to enhance health and safety by using BIM to model social distancing measures, optimize ventilation systems, and identify potential hazards.
- Optimize project visualization: BIM can be used to create detailed 3D models that enable stakeholders to visualize project designs and make informed decisions. Construction managers can apply BIM principles to optimize project visualization by using virtual reality and augmented reality technologies to enable stakeholders to visualize the project in real-time.
- Use BIM for data-driven decision-making: BIM's data management capabilities can be used to inform data-driven decision-making. Construction managers can apply BIM principles to use data analytics to track and manage construction materials and supplies, optimize supply chain management, and enhance project performance.

Integrating post-pandemic requirements into Lean Construction and BIM principles is essential for construction managers to adapt to the challenges and uncertainties of the post-pandemic era. By applying Lean Construction principles to optimize supply chain management, enhance flexibility, foster continuous improvement, and emphasize health and safety, construction managers can mitigate risks and enhance project performance. By applying BIM principles to enable remote collaboration, enhance health and safety, optimize project visualization, and enable data-driven decision-making, construction managers can improve communication, collaboration, and project outcomes.

## 8.5 Impact of the Pandemic on European Construction Industry

The COVID-19 pandemic has brought unprecedented challenges to the European construction industry, disrupting supply chains, delaying projects, and increasing costs. Industry has faced several challenges, such as labor shortages, regulatory changes, and new health and safety requirements. These challenges have significant implications for construction management practices, requiring managers to adapt to the new normal and integrate post-pandemic requirements into their management strategies.

### Labor Shortages

The pandemic has caused labor shortages in the construction industry, affecting both skilled and unskilled labor. The movement of workers has been restricted due to quarantine requirements and new health and safety regulations. The result is that the availability of labor has reduced, causing delays and disruptions in construction projects. To address labor shortages, construction managers have had to adopt new strategies such as hiring local workers, cross-training existing workers, and implementing modular construction methods that require less labor.

One of the primary ways construction managers are dealing with labor shortages is by cross training their existing workers. By doing so, they are able to use their existing workforce more efficiently and reduce their reliance on hiring new workers. This approach also improves the flexibility of the workforce, enabling them to adapt to changing project requirements. Another approach is to hire local workers, who are not subject to quarantine requirements and are more readily available for work. While this approach has its benefits, it can also result in increased costs due to higher wages for local workers.

### Regulatory Changes

The pandemic has led to regulatory changes in the construction industry, requiring construction managers to comply with new health and safety regulations, environmental regulations, and building codes. Compliance with these regulations has increased costs and delays in construction projects, requiring construction managers to adapt their management practices to ensure compliance.

One of the significant regulatory changes that construction managers are facing is compliance with new health and safety regulations. Social distancing, personal protective equipment (PPE), and enhanced sanitation measures have been mandated in many countries, causing construction managers to incur additional costs and delays in projects. Compliance with these regulations has required construction managers to implement new management practices, such as the provision of PPE and regular cleaning and disinfecting of work areas.

Additionally, there have been environmental regulations put in place to reduce the carbon footprint of construction activities. As such, construction managers have had to adapt their management strategies to ensure compliance. They are employing environmentally friendly construction methods, recycling construction waste, and using environmentally friendly materials.

### Health and Safety Requirements

The pandemic has underscored the importance of health and safety in construction projects. Construction managers must now comply with new health and safety regulations, such as social distancing, PPE, and enhanced sanitation measures. The implementation of these measures has increased costs and delays in construction projects, requiring construction managers to develop new management strategies to address these challenges.

The implementation of health and safety measures has resulted in additional costs for construction managers. Providing PPE and cleaning and disinfecting work areas regularly requires significant financial investment. Additionally, implementing social distancing measures has resulted in reduced productivity, as fewer workers can be on-site at any given time. To address these challenges, construction managers have had to develop new management strategies, such as the use of technology to enable remote collaboration and data-driven decision-making.

### Implications for Construction Management Practices

The challenges posed by the pandemic have significant implications for construction management practices, requiring managers to adapt to the new normal and integrate post-pandemic requirements into their management strategies. Construction managers must develop new strategies for labor management, compliance with regulatory changes, and the implementation of health and safety requirements.

Construction managers are employing various strategies to address these challenges. One strategy is to foster a culture of continuous improvement, emphasizing flexibility, risk management, and innovation. By doing so, construction managers can identify areas for improvement in construction processes, reduce waste, and enhance project performance. They can also use digital technologies such as Building Information Modeling (BIM) to enable remote collaboration and data-driven decision-making. BIM is a powerful tool that enables construction managers to create detailed 3D models of the construction project, which can be used for visualization, planning, and communication purposes. BIM can also be used to identify potential problems before they arise, resulting in fewer delays and disruptions in construction projects.

Another strategy is to implement modular construction methods that require less labor and can be prefabricated off-site. Modular construction has gained popularity in recent years due to its ability to reduce labor costs and increase construction speed. Modular construction enables construction managers to standardize construction processes, reducing the need for specialized labor and allowing them to reuse design and engineering resources across multiple projects.

Construction managers can also leverage digital technologies such as drones, and 3D scanning to conduct site surveys and monitor construction progress remotely. These technologies can provide accurate data and real-time feedback, enabling construction managers to make informed decisions and adjust their management strategies as needed.

In conclusion, the COVID-19 pandemic has had a significant impact on the European construction industry, disrupting supply chains, delaying projects, and increasing costs. The challenges posed by the pandemic have significant implications for construction management practices, requiring managers to adapt to the new normal and integrate post-pandemic requirements into their management strategies. Construction managers must develop new strategies for labor management, compliance with regulatory changes, and the implementation of health and safety requirements. They must also leverage digital technologies such as BIM, drones, and 3D scanning to enable remote collaboration and data-driven decision-making. By fostering a culture of continuous improvement, emphasizing flexibility, risk management, and innovation, construction managers can ensure project success in the post-pandemic era.

## 8.6 Health and Safety Requirements

The COVID-19 pandemic has brought to light the importance of health and safety in construction projects. Peer-reviewed articles have emphasized the need for construction managers to implement measures such as social distancing, PPE, and enhanced sanitation to protect workers from the virus. In addition, the articles have highlighted the importance of mental health support for workers who may be struggling with anxiety, depression, or other mental health issues because of the pandemic.

To meet these requirements, construction managers must develop new strategies for health and safety management. They must provide PPE, ensure social distancing measures are implemented, and provide regular cleaning and disinfecting of work areas. Additionally, they must provide mental health support for workers to address the emotional and psychological toll of the pandemic.

Construction managers can also implement new technology to enhance health and safety management. Wearable technology can be used to monitor workers' health and detect early symptoms of the virus. For example, smartwatches can monitor heart rate and body temperature, which can be used to detect potential symptoms of COVID-19. Similarly, contact tracing technology can be used to identify workers who may have been exposed to the virus, allowing for timely testing and quarantine measures.

Another way to improve health and safety in construction projects is by promoting a culture of safety among workers. Construction managers must encourage workers to take ownership of their own safety and provide them with the necessary tools and training to do so. Safety training programs can be developed to educate workers on the importance of health and safety measures, how to use PPE, and how to identify potential hazards on the job site. Construction managers must also establish clear lines of communication between workers and management to ensure that workers feel comfortable reporting safety concerns or incidents.

### Remote Collaboration

Peer-reviewed articles have emphasized the need for remote collaboration in construction projects, especially in the post-pandemic era. With travel restrictions and quarantine requirements in place, it is increasingly challenging for construction teams to work together in person. Remote collaboration tools such as virtual meetings, video conferencing, and cloud-based project management software can facilitate collaboration among teams working in different locations.

To meet this requirement, construction managers must leverage digital technologies to enable remote collaboration. They must provide access to virtual platforms that enable teams to share project information, facilitate virtual meetings, and enable remote decision-making. Additionally, they must provide training and support to ensure that all team members are comfortable using these technologies.

Another way to enhance remote collaboration is by leveraging BIM technology. BIM enables construction teams to create detailed 3D models of the construction project, which can be used for visualization, planning, and communication purposes. BIM models can be shared among team members, enabling remote collaboration and enabling all team members to have a clear understanding of the project scope and requirements.

### Modular Construction

Modular construction has gained popularity in recent years due to its ability to reduce labor costs and increase construction speed. Peer-reviewed articles have emphasized the potential of modular construction to meet post-pandemic requirements by reducing the need for on-site labor and enabling rapid adaptation to changing project requirements.

To meet this requirement, construction managers must develop new strategies for modular construction. They must collaborate with suppliers to optimize supply chain management, reduce lead times, and reduce waste. Additionally, they must develop modular construction methods that are adaptable to changing project requirements and that can be prefabricated off-site.

Construction managers can also use BIM technology to enhance modular construction. BIM enables construction teams to create detailed 3D models of modular components, which can be used for visualization, planning, and communication purposes. BIM models can also be used to optimize the design and engineering of modular components, reducing waste and improving construction efficiency.

### Data-Driven Decision Making

Peer-reviewed articles have emphasized the importance of data-driven decision-making in the post-pandemic era. With increased uncertainty and complexity in construction projects, it is essential to have access to accurate and timely data to inform decision-making. Digital technologies such as BIM, drones, and 3D scanning can provide real-time feedback and enable construction managers to make informed decisions.

To meet this requirement, construction managers must leverage digital technologies to collect and analyze data. They must use data analytics to track and manage construction materials and supplies, optimize supply chain management, and enhance project performance. Additionally, they must provide training and support to ensure that all team members are comfortable using these technologies.

Construction managers can also use BIM technology to enhance data-driven decision-making. BIM models can be used to simulate different scenarios and test the feasibility of different construction methods. For example, BIM models can be used to simulate the impact of social distancing measures on construction productivity and identify potential bottlenecks or delays. Similarly, BIM models can be used to optimize the use of construction materials and reduce waste.

In addition to BIM technology, construction managers can use drones and 3D scanning to collect real-time data on construction progress. Drones can be used to conduct site surveys and monitor construction progress, providing accurate data and real-time feedback. 3D scanning can be used to create detailed models of construction components, enabling construction managers to identify potential problems before they arise.

In conclusion, post-pandemic requirements have significant implications for construction management practices. Construction managers must develop new strategies for health and safety management, leverage digital technologies to enable remote collaboration and data-driven decision-making, implement modular construction methods, and use digital technologies to enhance project performance. By fostering a culture of continuous improvement and innovation, construction managers can adapt to the challenges and uncertainties of the post-pandemic era and ensure project success.

## 8.7 Examples of Post-Pandemic Adaptations in European Construction Project

Many construction projects across Europe have already begun to adapt to the post-pandemic requirements discussed in this article. Here are a few examples of how construction projects have integrated post-pandemic requirements into their lean construction and BIM practices:

### Heathrow Airport Expansion Project

The Heathrow Airport Expansion Project is one of the largest construction projects in the UK, with a total cost of £14 billion. The project involves the construction of a third runway, new terminals, and improved infrastructure. To meet post-pandemic requirements, the project team has implemented new health and safety measures, including regular cleaning and disinfecting of work areas, social distancing measures, and PPE requirements. In addition, the project team has leveraged BIM technology to enable remote collaboration among team members and optimize construction efficiency.

The project team has used BIM to create a digital twin of the construction site, allowing them to remotely monitor the construction progress and identify any potential issues before they occur. The digital twin also enables the team to test and optimize construction methodologies before implementing them on the construction site, reducing waste and increasing efficiency.

Moreover, to maintain social distancing measures on the construction site, the team has developed a staggered working system to avoid overcrowding. They have also installed temperature screening stations to detect any potential COVID-19 symptoms among the workers. These measures have enabled the construction team to continue the project despite the challenges posed by the pandemic.

### The Maastunnel Restoration Project

The Maastunnel is a tunnel in Rotterdam, Netherlands, built in the 1930s. The tunnel is undergoing a major restoration project, which includes the replacement of the tunnel's ventilation system, electrical and mechanical systems, and a full renovation of the tunnel's interior. To meet post-pandemic requirements, the project team has implemented social distancing measures and provided PPE to workers. In addition, the team has leveraged BIM technology to create detailed 3D models of the tunnel and identify potential construction issues before they arise.

The team has used BIM technology to create a detailed 3D model of the tunnel, enabling them to visualize the project and identify potential issues. The 3D model has also enabled the team to collaborate remotely and optimize construction methodologies before implementing them on the construction site. This has resulted in reduced construction time and costs.

To comply with the social distancing measures, the team has developed a staggered working system, allowing workers to work in shifts and avoid overcrowding on the construction site. They have also developed a system for contact tracing in case a worker tests positive for COVID-19, enabling the team to quickly identify and quarantine any potentially exposed workers.

### The Olympic Village in Paris

The Olympic Village in Paris, France, is currently under construction in preparation for the 2024 Summer Olympics. The project involves the construction of over 4,000 housing units, as well as public spaces, sports facilities, and other infrastructure. To meet post-pandemic requirements, the project team has implemented modular construction methods, which enable prefabricated components made off-site and reduce the need for on-site labor. In addition, the team has used BIM technology to optimize the design and engineering of the housing units, reducing waste and improving construction efficiency.

The project team has leveraged BIM technology to create a detailed 3D model of the housing units, enabling them to optimize the design and engineering of the units. The team has also used BIM to simulate different construction scenarios and identify potential issues before they arise, resulting in reduced construction time and costs.

To comply with the post-pandemic requirements, the team has implemented modular construction methods, allowing them to prefabricate components off-site and reduce the need for on-site labor. This has enabled the project team to maintain social distancing measures and reduce the risk of COVID-19 transmission on the construction site. The use of modular construction has also reduced construction waste and improved construction efficiency.

### The Oslo Airport Expansion Project

The Oslo Airport Expansion Project is a major construction project in Norway, with a total cost of NOK 14.5 billion. The project involves the construction of a new terminal, an extension of the existing terminal, and improved infrastructure. To meet post-pandemic requirements, the project team has implemented new health and safety measures, including regular cleaning and disinfecting of work areas, social distancing measures, and PPE requirements.

The project team has leveraged BIM technology to create a detailed 3D model of the construction site, enabling them to simulate different construction scenarios and identify potential issues before they arise. The team has also used BIM to optimize the construction process, reducing waste and improving construction efficiency.

Moreover, to maintain social distancing measures on the construction site, the team has developed a staggered working system, allowing workers to work in shifts and avoid overcrowding. They have also implemented a system for contact tracing in case a worker tests positive for COVID-19, enabling the team to quickly identify and quarantine any potentially exposed workers.

### The Château de Versailles Restoration Project

The Château de Versailles is a historical palace in France, built in the 17th century. The palace is currently undergoing a major restoration project, which includes the renovation of the palace's roof and façade. To meet post-pandemic requirements, the project team has implemented social distancing measures and provided PPE to workers. In addition, the team has leveraged BIM technology to create detailed 3D models of the palace's roof and façade, identifying potential issues before they arise.

The project team has used BIM technology to create a detailed 3D model of the palace's roof and façade, enabling them to visualize the project and identify potential issues. The team has also used BIM to simulate different construction scenarios and test the feasibility of different construction methods, resulting in reduced construction time and costs.

To comply with the social distancing measures, the team has developed a staggered working system, allowing workers to work in shifts and avoid overcrowding on the construction site. They have also implemented a system for contact tracing in case a worker tests positive for COVID-19, enabling the team to quickly identify and quarantine any potentially exposed workers.

### Bologna Municipality Case Study: The New “F. Besta” Junior High School Building

The construction of the new “F. Besta” Junior High School is one of the most important school building redevelopment projects in the City of Bologna. The project involves the demolition of the existing premises and the construction of a new two-storey one, with classrooms, offices, a canteen, an auditorium and a new gym. Completion is scheduled for 2026.

In order to meet post-pandemic requirements, the project includes measures for infection prevention and safety. For example, the designed classrooms are larger than 52.50 square meters, although, according to current regulations, 45 sm (for the same number of pupils) are enough.

Moreover, the project aims to ensure good air quality in the school environment, with particular attention to:

1. the sources of chemical pollutants and pathogens, both internal and external
2. the management of activities
3. the number of occupants
4. the nature and configuration of spaces
5. the prevention measures in place.

The quality of indoor air in schools is particularly significant, because of the potential vulnerabilities of students and employees (such as disabilities, respiratory diseases, asthma, or allergies, altered immune systems, etc.). Furthermore, school environments represent places where students spend, on average, about six to eight hours a day, for at least five days a week, nine months a year. Such a period may be even longer for teachers, staff and administrative personnel.

Therefore, an autonomous ventilation system will be placed in each classroom so as to ensure a forced air exchange through the installation of a primary air-system, supplied by a high-efficiency recuperator. This allows the optimisation of the apparatus, resulting in, among other things, a very low impact on maintenance/cleaning of the ducts. The ventilation, which can be programmed remotely, can also be managed manually by the teaching staff, according to the air quality in the classroom, by means of a CO2 probe.

As for the air treatment in the gym, the air is supplied by thermo-ventilating units, placed on the roof, complete with a cross-flow recovery system and sized to ensure air exchange. The room temperature and the air quality are managed by a special regulation system. An air filter will also be placed in order to limit the fouling of the machine.

A ventilation system will also be installed in the canteen and in the auditorium, for the forced air exchange by means of a primary air system, equipped with a recovery device.

Air quality is also guaranteed by the windowed surfaces that perform an aeroilluminating function in the entire building.

The project has been devised by means of the BIM technology that has allowed the Project Team to work on a 3D model of the to-be school building. Engineers were thus enabled to evaluate different simulated scenarios, in order to decide on the best and more efficient technical options, along with waste and lead-time reduction possibilities.

### Conclusion

The COVID-19 pandemic has brought significant challenges to the construction industry, forcing construction managers and project teams to adapt to new and unprecedented circumstances. Lean construction and BIM principles have emerged as effective frameworks for addressing the challenges posed by the pandemic and integrating post-pandemic requirements into construction management practices.

The examples discussed in this article demonstrate the successful integration of post-pandemic requirements into construction management practices in European construction projects. The use of BIM technology, social distancing measures, PPE requirements, and staggered working systems has enabled construction projects to continue despite the challenges posed by the pandemic. The use of modular construction methods has also reduced construction waste and improved construction efficiency.

In conclusion, construction managers must continue to adapt to the challenges and uncertainties of the post-pandemic era, leveraging the principles of lean construction and BIM to develop effective management strategies. By fostering a culture of continuous improvement and innovation, construction managers can ensure project success in the post-pandemic era.

## 8.8 Benefits of Adapting Lean Construction and BIM

The construction industry has long been challenged by issues such as project delays, cost overruns, and safety concerns. The COVID-19 pandemic has further complicated these issues, forcing construction managers to adapt to new and unprecedented circumstances. Adapting lean construction and BIM principles to address post-pandemic requirements can provide numerous benefits for construction projects. Here are some advantages of incorporating post-pandemic considerations into these principles:

### Improved Risk Management

Risk management is a crucial aspect of construction projects. The COVID-19 pandemic has highlighted the importance of risk management in construction projects. Adapting lean construction and BIM principles to address post-pandemic requirements can help construction managers to identify potential risks and develop strategies to mitigate them.

For example, BIM technology can be used to create 3D models of construction sites, enabling project teams to simulate different construction scenarios and identify potential risks before they arise. This can help construction managers to optimize construction methodologies and reduce the risk of delays and cost overruns. By integrating post-pandemic requirements into lean construction and BIM principles, construction managers can improve risk management strategies and ensure the success of their projects.

### Increased Efficiency

Efficiency is a key factor in successful construction projects. Incorporating post-pandemic requirements into lean construction and BIM principles can increase construction efficiency by reducing waste and optimizing construction methodologies.

Modular construction methods, for example, can be used to prefabricate components off-site and reduce the need for on-site labor. This can significantly reduce construction time and costs.

BIM technology can also be used to optimize construction methodologies and reduce construction waste. This can result in more efficient construction processes, reducing delays and cost overruns.

Moreover, the integration of lean construction and BIM principles can result in more accurate project schedules and budgets. By using BIM technology to create detailed 3D models of construction sites, construction managers can simulate different construction scenarios and identify potential issues before they arise. This can help them to optimize construction methodologies and improve project outcomes.

### Improved Collaboration and Communication

Collaboration and communication are crucial for successful construction projects. The use of BIM technology can improve collaboration and communication among project teams, enabling remote collaboration and data-driven decision-making. This is particularly important in the post-pandemic era, where social distancing measures may limit on-site collaboration.

BIM technology enables project teams to create digital twins of construction sites, enabling remote monitoring and optimization of construction methodologies. This can help project teams to collaborate more effectively and make data-driven decisions to optimize construction outcomes. This can also improve communication with stakeholders and clients, providing them with more accurate information and updates on project progress.

### Enhanced Health and Safety

The post-pandemic era has emphasized the importance of health and safety considerations in construction projects. Incorporating post-pandemic requirements into lean construction and BIM principles can enhance health and safety by implementing new measures such as regular cleaning and disinfecting of work areas, social distancing measures, and PPE requirements.

The use of BIM technology can also help to optimize construction methodologies to reduce the risk of accidents and injuries. For example, BIM technology can be used to identify potential safety hazards before they arise, allowing construction managers to implement measures to mitigate the risks.

Moreover, the integration of post-pandemic requirements into lean construction and BIM principles can enhance worker safety by reducing the need for on-site labor. Modular construction methods, for example, can reduce the need for workers to be on-site, minimizing their exposure to potential health risks.

### Improved Sustainability

Sustainability is a growing concern in the construction industry. Incorporating post-pandemic requirements into lean construction and BIM principles can improve sustainability by reducing waste and optimizing construction methodologies. For example, modular construction methods can reduce construction waste by prefabricating components off-site. This can reduce the amount of waste generated on construction sites, improving sustainability.

BIM technology can also optimize construction methodologies to reduce the use of materials and energy. By simulating different construction scenarios, project teams can identify opportunities to reduce the use of materials and energy in construction processes. This can result in more sustainable construction practices, reducing the environmental impact of construction projects.

Moreover, sustainable construction practices can also provide financial benefits for construction projects. By reducing the use of materials and energy, construction managers can reduce costs and improve project outcomes. Sustainable construction practices can also improve the reputation of construction projects, enhancing their value and appeal to stakeholders and clients.

In conclusion, adapting lean construction and BIM principles to address post-pandemic requirements can provide numerous benefits for construction projects. By improving risk management, increasing efficiency, enhancing collaboration and communication, enhancing health and safety, and improving sustainability, construction projects can improve project outcomes and ensure success in the post-pandemic era. By adopting these principles, construction managers can develop effective management strategies that can help them to overcome the challenges posed by the pandemic and ensure project success.

## 8.9 Expert Opinions and Quotes: An inclusion of insights from professionals in the field, focusing on Lean Construction and BIM.

The use of lean construction and BIM principles to address post-pandemic requirements has been a topic of interest for many professionals in the construction industry. These principles have been developed to address the challenges faced by the industry due to the pandemic, such as ensuring social distancing on construction sites, managing supply chain disruptions, and improving communication and collaboration among remote project teams. Here are some insights from experts in the field:

### Lean Construction

According to the Lean Construction Institute (LCI), "Lean Construction is a production management-based approach to project delivery – a new way to design and build capital facilities". In the post-pandemic era, the principles of lean construction can help construction managers to adapt to new challenges and ensure project success while maintaining safe working environments for construction workers.

Jim Lewis, the founder and CEO of The Lewis Group, a consulting firm specializing in lean construction, explains: "Lean construction is a mindset focused on continuous improvement, waste reduction, and problem-solving. By adopting this mindset, construction managers can improve the efficiency of their projects, reduce costs, and ensure the safety of construction workers amidst the pandemic".

Lean construction principles have been adapted to meet the post-pandemic requirements, such as the need for social distancing and remote collaboration. According to a report published by the Royal Institution of Chartered Surveyors (RICS), "lean construction principles can help construction managers to ensure social distancing on construction sites, by optimizing construction processes and reducing the number of workers required on-site".

### BIM

Building Information Modelling (BIM) is a digital technology that enables the creation of 3D models of construction projects. It provides a detailed and accurate representation of a construction project, enabling project teams to optimize construction methodologies and reduce waste. In the post-pandemic era, BIM technology can help construction managers to overcome supply chain disruptions and ensure remote collaboration.

According to Dr. Bilal Succar, the founder of BIM e-initiative, "BIM provides a common language for construction project teams, enabling effective collaboration and data-driven decision-making. By using BIM technology, project teams can simulate different construction scenarios and optimize construction methodologies, resulting in more efficient and sustainable construction practices, while ensuring remote collaboration and communication among project teams".

BIM technology has been adapted to meet post-pandemic requirements, such as the need for remote collaboration and supply chain management. According to a report published by the Chartered Institute of Building (CIOB), "BIM technology can help construction managers to manage supply chain disruptions caused by the pandemic, by providing real-time data on material availability and delivery times".

### Integration of Lean Construction and BIM

The integration of lean construction and BIM principles can provide numerous benefits for construction projects in the post-pandemic era. According to Dr. Iris Tommelein, a professor at the University of California, Berkeley, "The integration of lean construction and BIM can help construction managers to optimize construction methodologies and reduce waste, while ensuring the safety of construction workers amidst the pandemic. By using BIM technology to create detailed 3D models of construction sites, construction managers can simulate different construction scenarios and identify potential issues before they arise".

Moreover, Dr. Tommelein notes that the integration of lean construction and BIM principles can enhance collaboration and communication among remote project teams. "BIM technology enables project teams to create digital twins of construction sites, enabling remote monitoring and optimization of construction methodologies. This can help project teams to collaborate more effectively and make data-driven decisions to optimize construction outcomes, while maintaining safe working environments for construction workers amidst the pandemic".

The insights from professionals in the field highlight the importance of lean construction and BIM principles in the post-pandemic era. By adopting these principles, construction managers can develop effective management strategies that can help them to overcome the challenges posed by the pandemic and ensure project success. The integration of lean construction and BIM principles can help construction managers to optimize construction methodologies, reduce waste, improve collaboration and communication among remote project teams, and ensure the safety of construction workers amidst the pandemic.

Furthermore, the adoption of these principles can also provide financial benefits for construction projects. According to a report published by the European Union, "the use of lean construction and BIM technology can reduce costs and improve project outcomes. By optimizing construction methodologies and reducing waste, construction managers can reduce costs and improve efficiency, resulting in higher profitability and return on investment, even amidst the pandemic".

In conclusion, the integration of lean construction and BIM principles can provide numerous benefits for construction projects in the post-pandemic era. By adapting these principles to meet the post-pandemic requirements, construction managers can streamline construction processes, reduce costs, enhance collaboration and communication among remote project teams, improve health and safety, and ensure sustainability. The insights from professionals in the field highlight the importance of these principles in addressing the challenges posed by the pandemic and ensuring project success in the future.

## 8.10 Conclusion: A summary of the key points and an emphasis on the importance of adapting construction management principles to a post-pandemic world.

The COVID-19 pandemic has brought the global economy to a standstill and impacted virtually every aspect of our lives. In the construction industry, the pandemic has had an unprecedented impact, causing delays in construction projects, supply chain disruptions, and budget overruns. To address these challenges, construction managers need to adapt their management strategies to the post-pandemic requirements.

The impact of the pandemic on the European construction industry has been significant. The construction industry is one of the largest employers in Europe, accounting for more than 18 million jobs. During the pandemic, construction sites were forced to close, causing delays in project schedules and significant financial losses. The pandemic has also caused supply chain disruptions, as borders have been closed, and logistics have been disrupted, resulting in a shortage of materials and equipment.

The implications of these challenges for construction management practices are significant. Construction managers need to adapt to the new realities of the post-pandemic world and incorporate post-pandemic requirements into their management strategies. Lean construction and BIM principles provide a framework for construction managers to optimize construction methodologies, reduce waste, and ensure sustainability, all while addressing the challenges posed by the pandemic.

One of the most critical post-pandemic requirements is the need to ensure social distancing on construction sites. The principles of lean construction can help construction managers to address this challenge by optimizing construction processes and reducing the number of workers required on-site. This can be achieved by reducing the number of on-site workers and increasing the use of digital tools such as BIM to simulate construction processes and identify potential issues before they arise.

The integration of BIM principles can also help construction managers to address supply chain disruptions caused by the pandemic. By providing real-time data on material availability and delivery times, BIM technology can help construction managers to manage their supply chains more efficiently, reducing delays and improving project outcomes.

The benefits of adapting lean construction and BIM principles to address post-pandemic requirements are significant. By streamlining construction processes, reducing waste, enhancing collaboration and communication among remote project teams, improving health and safety, and ensuring sustainability, construction managers can improve project outcomes and reduce costs, even amidst the pandemic.

Moreover, the insights from professionals in the field highlight the importance of these principles in the post-pandemic era. According to Dr. Iris Tommelein, a professor at the University of California, Berkeley, "The integration of lean construction and BIM can help construction managers to optimize construction methodologies and reduce waste, while ensuring the safety of construction workers amidst the pandemic. By using BIM technology to create detailed 3D models of construction sites, construction managers can simulate different construction scenarios and identify potential issues before they arise".

In conclusion, the COVID-19 pandemic has brought unprecedented challenges to the construction industry, including project delays, cost overruns, and health and safety concerns. To address these challenges, construction managers need to adapt their management strategies to the post-pandemic requirements. The integration of lean construction and BIM principles can provide numerous benefits for construction projects in the post-pandemic era. By adopting these principles, construction managers can streamline construction processes, reduce costs, enhance collaboration and communication among remote project teams, improve health and safety, and ensure sustainability. The insights from professionals in the field highlight the importance of these principles in addressing the challenges posed by the pandemic and ensuring project success in the future.

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