Technical Paper **Open Access**

Reinhard F. Wagner*

EPC 4.0: The quest for reducing CAPEX in EPC projects

DOI 10.2478/otmcj-2020-0020
Received: December 25, 2019; accepted: May 08, 2020

Abstract: Engineering, procurement and construction (EPC) business in Europa is increasingly under pressure. Lack of productivity, low or negative profit margins for investors, and the lack of adopting necessary innovations and digitalization—from engineering activities through operations and maintenance to decommissioning—have caused significant deprivation of business and competitiveness compared to emerging providers in Asia. The quest for reducing capital expenditures (CAPEX) in EPC projects is intensifying. In May 2018, a research project was started to analyze the situation and key trends through desk research, to research how the challenges of the business could be tackled and to derive practical guidance for EPC contractors as well as for investors, owners, and operators (O/O). The project aimed to propose innovative ways of improving the EPC business model to reach the next level ("EPC 4.0"). In doing so, lessons learned from the automotive and aviation industry were considered. A key objective of the research project was to challenge statements of international EPC experts to cut CAPEX by 40–50% in EPC projects. With this statement in mind, the research focused on identifying measures with potential in six areas: (1) digitalization, (2) partnering, (3) flat supply chains, (4) flexible organizations, (5) core competences, and (6) the human factor. Summarizing the findings in these areas, the EPC 4.0 project came to a savings potential of up to 50% of the total budgeted project costs.

Keywords: EPC, CAPEX, competitiveness, productivity, digitalization, partnering, human factor

***Corresponding author: Reinhard F. Wagner,** Tiba Managementberatung GmbH, Board of Directors, Munich, Germany. E-mail: reinhard.wagner@tiba.de

1 Introduction

The financial crisis in 2008 and the oil price crash in 2014 severely hit the profitability of operations in the oil and gas, chemical, energy, and other associated industries, and consequently, the engineering, procurement and construction (EPC) business that is built on the investments in these industry sectors. Low commodity prices in recent years have continued to discourage investors from financing industrial production. The industry is still suffering even after a full decade, but not only because of this crisis. Low productivity growth, low degree of digitalization, and low investment in R&D have disconnected this industry from the positive evolution that other industries have experienced over the last 10–20 years—the stock market is celebrating successes elsewhere. While the Dow Jones Industrial Average (DJIA) increased in the 10 years from 2008 to 2018 by more than 80%, the Dow Jones Construction Index fell by 30% in the same period.

However, there is still a significant demand for industrial plants. The world population is growing; production output will continue to grow on a global scale, and the need to build new production facilities will do, too. The backlog of 10 lost years for the EPC industry is immense. Brownfield investments to revamp existing facilities add to this huge market. The engine of the EPC business has started up again. But nothing will be the same as before 2008 because the traditional business model in EPC has no future.

Prominent voices are calling on the industry to cut its capital expenditures (CAPEX) by 40–50%. This doesn't just mean fine-tuning of performance; this ambitious target necessitates radical changes. Within the entire value chain from CAPEX to OPEX, from the EPC of industrial plants to their operation and maintenance, money is wasted as a result of disastrous project planning and execution, and inefficient operations. Money is spent that does not add any value to basic business objectives. The Construction Industry Institute (CII, Texas) determined that 40% of project costs are just transactional costs—imagine the potential of cutting these down! A radical

business transformation that would put the EPC business on par with the efficiency of the automotive or aviation industry would unleash money from investors. There is no lack of money. The EPC sector is simply not effective enough to attract it!

In May 2018, a German think tank kicked off an innovation initiative to develop practical guidance for EPC contractors as well as for investors, owners, and operators on how to approach innovative business models for industrial projects and operations, from EPC to O&M. The research focused on qualitative methodology rather than on quantitative figures to capture the nuances of practice and provide insights from practitioners for practitioners. Wherever quantitative figures are referred to, they are intended to indicate the "hidden potential" and should not be misunderstood as statistic values.

Based on practical experience, an in-depth analysis of the present situation, key trends for the business, and the need for change was done, scanning a multitude of reports, articles, conference proceedings, and literature. Ideas on how business could improve were developed and validated during in-depth interviews with 20 industry representatives. During conferences and intensive workshops, potential solutions were discussed and refined, before an online survey captured the magnitude of cost reductions in each area. Case studies were identified for each improvement area, highlighting the realization of improvements in practice and discussing advantages together with disadvantages.

This article summarizes the actual situation and key trends, highlights the potentials for improving the EPC business with targets for CAPEX savings, and concludes on the results. The final report of the research project was released in 2019 (Ritsche et al. 2019).

2 Situation of the EPC business

The term "EPC" refers to a particular form of contracting arrangement used in some industries where an EPC contractor is made accountable for a multitude of activities—from design, procurement, construction, to commissioning and handover of the deliverables to the owner or operator. EPC projects are typically large and complex. They can be found in many industry segments, including but not limited to industrial plants, oil and gas, mining, power generation, or large infrastructure (Ritsche 2019; Wagner 2019).

September 15, 2008 is a historical milestone that marks a turning point for the EPC industry. The day Leman Brothers collapsed and stock exchanges around

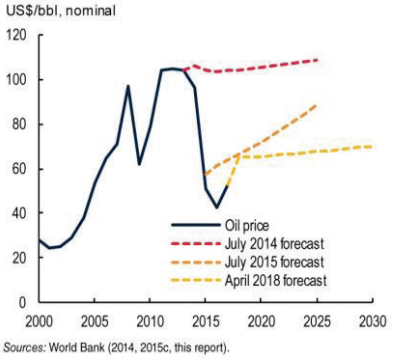

Fig. 1: Commodity Markets Outlook, April 2018 (Worldbank 2018).

the world lost billions of Dollars was the starting point for one lost decade in EPC business. The price of crude oil is the most prominent indicator determining the overall economic performance. The World Bank publishes its outlook (Worldbank 2018) of commodity prices quarterly, and owners/operators of industrial plants producing commodities carefully plan their investments in step with this prognosis.

The oil price had climbed to an unprecedented spike in 2008, driven by the rapidly increasing demand in the emerging economies but also production cuts by the Organization of the Petroleum Exporting Countries, before it collapsed as a consequence of the global recession triggered by the financial crisis in 2008 (see Figure 1).

Economic recovery sent back the oil prices to levels above 100–125 USD between 2010 and 2014, before it suffered another steep drop in 2014. This second drop was caused by the same economies that fueled the oil price with their massive demand the years before and then struggled to maintain their growth, above all China, followed by India, Russia, and Brazil. The high oil prices from 2010 to 2014 triggered North America to expand its capabilities to extract the black gold from its oil sands, further contributing to the negative effect of low demand. Last but not least, Saudi Arabia continued to exploit its resources with high production levels. All in all, the oil price collapsed to levels down to 40 USD and has not recovered since. The World Bank forecast has been corrected to lower levels in recent years, and the pressure remains on all investors to plan their business based on continuously low commodity prices, putting high pressure on CAPEX as well as OPEX.

As a consequence of the collapse not only of the oil price but also of the price of other commodities such as natural gas, owners put their investments on hold. The result was a dramatic decline in order intake for those companies that were relying on orders from industrial

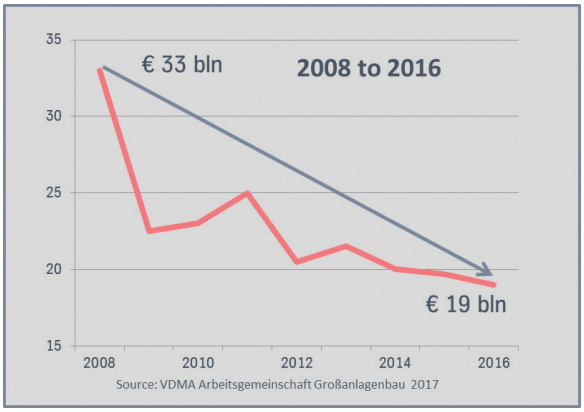

Fig. 2: Order intake for large EPC projects in Germany 2008–2016 (VDMA 2017a).

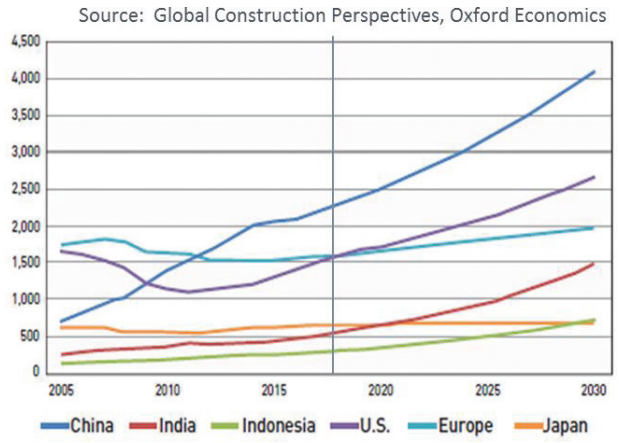

Fig. 3: Forecast of the global construction market 2030 (Global Construction 2015).

plant operators, EPC contractors, the supply chain of manufacturers, but also service providers in all fields, including operation and maintenance.

The strong decline in order intake hit developed economies such as Germany especially hard. The VDMA (Germany´s Mechanical Engineering Industry Association) determined that the order intake for the large EPC projects by German companies dropped from 33 billion Euros in 2008 down to 19 billion Euros in 2016 (VDMA 2017a) (see Figure 2). Companies with low capital assets collapsed, others were forced to merge, and yet others were subject to acquisition by healthier competition, often based in Asia.

The rise of China is another game-changing factor for the global economy, and specifically in the EPC business. While western economies are lacking long-term strategies, western governments acting from one election to the next, and western companies acting from one quarterly report to the next, China´s strength is long-term planning. China is investing where the return-on-investment may pay back not before 5, 10, or even 20 years, while western companies are struggling with the massive decline in their business and consequently cannot release the cash to invest.

Global competition has always been strong, and companies have their strategies to face this competition. Competition from China, however, is felt as the toughest-ever threat to European companies. There is only one way out: European companies have to remember their strengths and have to invest in the fields of their strengths and have to defend—or regain—their leading position. Without investment into long-term strategies, this contest will be lost by European companies. The good news is: after a lost decade for the EPC business and after a decade of low demand for industrial production facilities, this market is starting up again. The backlog of one decade is immense, and the growing world population will guarantee a continuous demand for new capital projects. The market is big enough for it to require all available engineering resources in this world.

There is no precise definition of "EPC Industry"; consequently, there are no reliable reports that determine the size of the global EPC market. Many reports refer to the global construction market, which is estimated to be a 10 trillion USD market today and is expected to grow to 15 trillion USD by 2030 (Global Construction 2015). Growth is primarily driven by the economies in China, India, the US, and Southeast Asian economies such as Indonesia, while the traditional players Europe or Japan may recover but will not surpass the levels before the financial crisis in 2008 (see Figure 3). Construction industry includes real estate and infrastructure, which make up the largest part of the market, but it can be assumed—depending on the definition of EPC industry—that EPC business has a share of 6–10% of this market.

Global market size for EPC projects of 600–1,000 billion USD per year, and market growth of 50% over the next 15 years requires all players in this market to organize themselves more effectively to be in a position to execute all these projects. Considering that we are currently executing projects with an average cost overspend of more than 30%, there are huge opportunities in this market that would justify massive investments into the companies that execute these projects. However, as long as there is a poor performance of the EPC industry compared to other industries, investors are reluctant to invest in this business.

Investors are driven by leading financial indicators. The DJIA dropped dramatically with the financial

crisis in 2008; however, it managed to recover to previous heights within 5 years. Within one decade (01/2008 to 01/2018), the DJIA increased by 86%—attractive for those who invested their money in this market. The Dow Jones US Heavy Construction Index (DJCI) is a leading indicator for the construction industry in general and (to a certain extent) can be taken as an indicator for the EPC industry. The DJCI suffered a dramatic drop in 2008 as well, but even after 5 years, it remained 30% below its precrisis level. Another 5 years later, its performance had still not improved. While investors celebrated the record heights of the DJIA, those investing in the market represented by the DJCI suffered 30% losses after one lost decade.

There are several reasons for the massive underperformance of this sector, and there is a wealth of studies (e.g. Barshop 2016; Flyvbjerg 2017) and reports by business consultants that come to very similar results. From all these studies, three major factors are highlighted here:

2.1 Poor performance in the execution of capital projects

Studies, for example by McKinsey (McKinsey 2017a), conclude that capital projects are completed with an average of 37% cost overspend and 53% schedule overrun. The magnitude varies from sector to sector, but the oil and gas downstream business seems to hold the record with an average of 53% cost overspend (see Figure 4).

The reasons for these massive losses have been analyzed, and the conclusions are as follows (McKinsey 2017a): "The failures in the core processes of project under-performance are well understood: post-project reviews generally audit the systems, process, and project management root causes for overruns. However, the disruptive influence of failures in project leadership, ineffective culture of the project organization, failed mechanisms of collaboration between multiple parties involved—and their increasing importance as the scale and complexity of projects increase—are typically not examined to the same extent."

The report for the World Economic Forum in May 2016 prepared in collaboration with Boston Consulting Group (BCG 2016) refers to these reasons for failure:

- Lack of innovation and delayed adoption
- Informal processes or insufficient rigor and consistency in process execution
- Insufficient knowledge transfer from project to project
- Weak project monitoring
- Little cross-functional cooperation
- Little collaboration with suppliers
- Conservative company culture
- Shortage of young talent and people development

2.2 Poor productivity growth compared to other sectors

Productivity has grown continuously over the last few decades, between 50 and 70% for the overall economy within the past 20 years. Manufacturing has been leading productivity growth, almost doubling its real gross added value per hour worked by a person employed between 1995 and 2015 (McKinsey 2017a). Productivity in construction registered minor growth during the same period (see Figure 5).

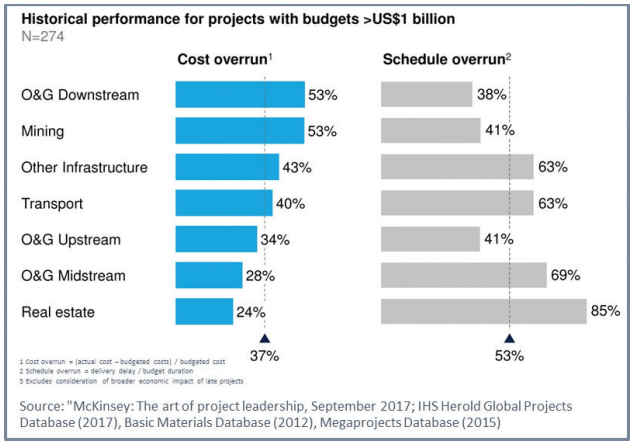

Fig. 4: Performance of megaprojects (McKinsey 2017a).

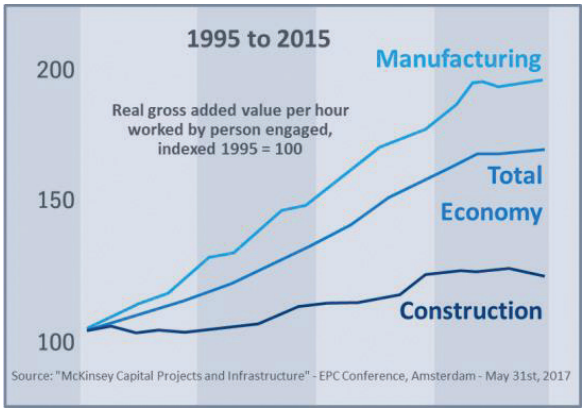

Fig. 5: Productivity in construction (McKinsey 2017a).

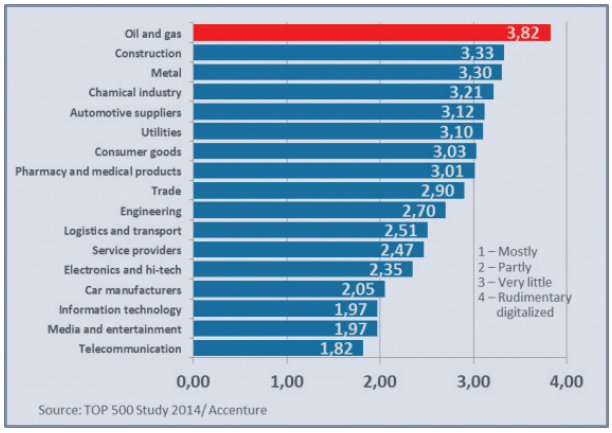

Fig. 6: Digitalization by sectors (Riemensperger et al. 2015).

2.3 Low level of digitalization

Another explanation for the massive productivity gap of our business in comparison with other industrial sectors is the low level of digitalization (VDMA 2017b). Again, we can refer to several analyses performed by major business consultancies, in this case, the TOP 500 Study 2014 by Accenture (Riemensperger et al. 2015) (see Figure 6).

While the elimination of the deficiencies that lead to massive under-performances in the execution of projects is an obvious measure to be taken by all companies in this sector, the players shall focus on the opportunities expected from closing the gap in the industry ranking (first) in digitalization, resulting (second) in the productivity growth that this industry needs to compete successfully for the investors´ money in the global market.

3 Key trends for the EPC business

The starting point of this "EPC 4.0" initiative was the White Paper "Time for Change—A vision for EPC 4.0" issued by Project Team in November 2017 (Ritsche 2017). From the variety of studies and reports that analyze the situation in the EPC sector, and from the variety of issues that are addressed by speakers at conferences held over the globe, the research project extracted key trends for its research:

3.1 Collaboration between O/O and EPC contractor

The traditional approach in EPC business to execute a project based on a lump-sum turn-key (LSTK) contract between the owner/operator and EPC contractor is adverse to the idea of joint collaboration. The LSTK contract causes each contractual party to focus on its claims against the other party and adds additional contingencies to budgets and schedules to protect against claims and to deal with uncertainties.

There is a trend for investors to think about strategies on how to marry CAPEX and OPEX and form one integrated project team with the key players for the execution of the CAPEX project. Project alliance contracts are one model in which each party is incentivized to optimize both the CAPEX and the OPEX of the plant. Uncertainties and the consequential contingency costs are reduced owing to open books. Sustainable long-term-goals should prevail before short-term deadlines.

3.2 Collaboration with the supply chain

The traditional approach contracting the work from the top (O/O) to bottom through several levels to the EPC contractor, subcontractors, and their sub-suppliers in a contractual hierarchy generates losses of 40% of project costs as transactional costs. Relational contracting rather than roll-up contracts will flatten the supply chain, replacing the contracting hierarchy with a network.

Modularization and standardization are good measures to improve the integration of the supply chain into the plant design, but standardization to cut CAPEX should not compromise any optimization of OPEX. Many components, however, are over-specified, and costs can be saved by eliminating these over-specifications. Scalable and agile platform strategies, such as in automotive design, permit standardization without eliminating necessary variances.

The traditional approach is to buy and own the equipment. A different approach is to lease equipment over a period of time, which levels CAPEX costs. Alternatively, equipment may be paid-per-use, with the equipment supplier remaining the owner and maintaining the equipment over the life-time. This option could be attractive for suppliers of complex machinery, not only because of the profit generated in service contracts but also because of the opportunity to feed experience from operation and maintenance back into design improvements.

3.3 Flexible resourcing and agile EPC collaboration

Labor markets in high-cost countries do not provide sufficient qualified resources, with the consequence of further increasing labor costs. Companies with global hubs are shifting qualified work to low-cost countries.

Fluctuations of staff (e.g. job-hopping), as experienced in Asia, will become common in high-cost countries, too. Highly qualified staff is not willing to accept cuts but moves on to where the work seems more attractive. Agile practices are increasingly adopted in EPC projects (Koschke 2019).

Companies are taking the approach of replacing hierarchies with network organizations that develop the flexibility to upscale and downscale their capacities to accommodate the huge upturn and downturn cycles in EPC business.

3.4 Digitalization and Industry 4.0/data and knowledge sharing

Potential new players might position themselves as providers of EPC as a Service and/or project management consultancy. They would offer a software-based solution and apply building information modeling (BIM) to manage the development and construction of a capital project.

The opportunities of digitalization and industry 4.0 will require the EPC contractor and the owner/operator to build a partnership over the asset life cycle. The real value can be generated when the technology provider shares his engineering data with the operator, and the operator shares his O&M data with the technology provider. The analysis of big data from multiple plants leads to plant and process improvements that both technology provider and operator benefit from.

3.5 Project management and competencies

Projects fail because the established and known project management methods and tools are not applied (Ritsche 2019). This is not about innovation; this is about bridging the gap between theory and reality between knowing what's wrong and doing what's right. The problem is not that processes or tools must be invented; the problem is the change of mindset in the organizations and their people and how to manage a culture of change.

Agile project management methods are successfully applied in other industries, especially in innovation-driven businesses, such as software development. There may be a conflict between the necessity to digitalize the project management processes with controlled data workflows that may lack flexibility and the trend to agile project management methods. This conflict needs to be addressed and resolved.

4 Hidden potential of the EPC business

Today, industries are under permanent pressure to change and adapt. Innovative technologies, products, and services brought to market by companies in global competition create a race for leadership in all sectors of the economy. European companies in the EPC business cannot escape this pressure and aspire to catch up in this global race. However, much remains to be done as the EPC business in Europe has fallen far behind in recent years and must now make even greater efforts.

In recent years, studies have repeatedly revealed the gaps in European EPC business in terms of innovation, productivity, profitability, and business agility. European companies in the automotive, aerospace, mechanical and electrical engineering, as well as automation industries have worked continuously to improve their performance in recent years and are now among the global champions. The European EPC business needs to catch up and improve performance significantly. This is not a question of marginal improvement, but a quantum leap.

Prominent voices in the European EPC business are calling for significant changes, for example, the Global EPC Manager of Shell, Paul van Weert, who advocated during the ECI Annual Conference ´18 (ECI 2018) in Amsterdam: "We need to halve the cost of capital projects to enable them to do twice as many projects with the same allocated budget, not through putting more cost pressure on supply chains, but through fundamentally rethinking the delivery model."

In summary, a step-change in the way projects are executed is needed to secure the improvement of up to 50% in cost and 30% in the schedule. That won't be achieved by squeezing the margins of suppliers, but calls for much deeper collaboration, more rigor in scoping projects, relying more on what the industry has on offer, standardization, less prescriptive standards from the client and using digital twins more effectively from design through construction to the operation phase.

Stephen Mulva, Director of the CII, paints a dramatic picture of the situation and argues that the transactional costs are too high (CII 2018): "For the past several decades, our industry has emphasized the planning, technical, managerial, and work process dimensions of our projects—at the expense of the numbers and the assets keeping us in business. Forty percent (40%) of the cost of creating a new asset is currently wasted on transactional costs. It's not a sustainable model. We have to employ the best business, financial, and accounting concepts and we've got to do it now."

Transactional costs may be defined as costs associated with the exchange of goods or services, including payments to banks and brokers, search fees, as well as service fees to process these transactions. In EPC business, transactional costs may also include financial fees, legal fees, dispute resolution costs along with logistics and communications costs. It also includes foundational work such as the cost of sourcing quotes, cost and schedule benchmarking, assurance reviews, and so forth. Unfortunately, in EPC projects, transactional costs thrive owing to both lack of integration and to contractual and operational frictions between the multitude of stakeholders involved during the project lifecycle.

Mulva advocates a new approach, the "Operation System 2.0" (CURT 2018). This vision is a multi-industry, collaborative, research-supported effort that aims to reorganize industry procedures and standards and replace them with a standardized, technology-enabled platform that accommodates future changes and makes capital projects more financially viable and sustainable.

In an interview with d1g1tal AGENDA (2018), he points out the impact: "The existing business model is essentially like a pyramid: At the top, you have the owner, followed by the EPC, a series of subcontractors, a series of suppliers, and they are working on the contract, both upwards and downwards. This model is very slow and expensive. With computers and AI, we are able to put everybody on what we call the Thin Platform OS 2.0. The impact can reach up to 35% cost reduction, 50% cycle time reduction, 57% better ROCE, and 250% more projects."

In 2017, an in-depth report of McKinsey experts examined the role of technology in shaping modern industries (McKinsey 2017b). The authors conclude that digitization is driving a "radical reordering of traditional industry boundaries," leaving whole sectors ripe for disruption. "The mobile Internet, the data-crunching power of advanced analytics, and the maturation of artificial intelligence (AI) have led consumers to expect fully personalized solutions, delivered in milliseconds. Ecosystem orchestrators use data to connect the dots - by, for example, linking all possible producers with all possible customers, and, increasingly, by predicting the needs of customers before they are articulated. The more a company knows about its customers, the better able it is to offer a truly integrated, end-to-end digital experience, and the more services in its ecosystem it can connect to those customers, learning ever more in the process."

In another McKinsey report concerning "The art of project leadership: Delivering the world´s largest projects" (McKinsey 2017a), it is stated that "troublingly, large capital projects that are completed on schedule and within budget are the exception, not the rule. We reviewed a dataset of more than 500 global projects above the US $1 billion in resource industries and infrastructure and found that only 5 percent of projects were completed within their original budget and schedule. In completed projects, the average cost overrun was 37 percent and average schedule overrun was 53 percent." It is pointed out that the disruptive influence of failures in project leadership, ineffective culture of the project organization, failed mechanisms of collaboration between multiple parties involved are some of the levers for improving the performance of large projects, especially as scale and complexity of projects are increasing.

Last but not least, the productivity gap in the EPC business must be dealt with. Reports (McKinsey 2017c) point to the fact that in the construction industry, the annual productivity growth during the last two decades has been only 1%, that the industry is lagging behind overall economy productivity by 50% and that in total a boost in productivity of approximately 50-60% could be achieved, which amounts to $ 1.6 trillion additional value:

"Construction is among the most fragmented industries in the world, the contracting structures governing projects are rife with mismatched risk allocation, and owners and buyers, who are often inexperienced, must navigate a challenging and opaque marketplace. The results are operational failures within firms, including inefficient design with limited standardization; insufficient time spent on planning and implementing the latest thinking on project management and execution; and a low-skilled workforce. In addition, the construction industry is highly volatile and has bottom-quartile profit margins compared with other sectors, constraining investment in the technology and digitization that would help raise productivity."

Summing up all the findings, there is a real potential for the EPC business to improve its overall performance. All reports show measures for drastically reducing costs as well as scheduled times, for improving the overall productivity by learning from good practices and other industries, performing systematic organizational change, and by using modern technologies to the best extent.

5 Results and conclusions

After studying a multitude of reports, discussing the matters with about a hundred experts and analyzing more than a dozen case studies, the research project was able to conclude that it's possible to save more up

to 50% of CAPEX in EPC projects! However, unleashing the potential depends on a number of factors that need to come together.

First of all, the EPC business is complex, and every business, every project is special. There is no standard solution that fits all. Solutions that may work in one business case might fail in the other, as ownership structures, regional aspects, technical conditions or the markets are completely different. This is why the research had to consider a multitude of perspectives.

Second, no individual player within the value chain will accomplish this target on their own. CAPEX is the total of CAPEX, including the costs of project development, the costs of engineering/procurement/construction, the cost of project management, and project governance. Such a radical reduction may only be feasible if developed along the entire value chain, and here the first link in the chain is the investor. The investor defines the strategy for project development and decides between the traditional "LSTK" approach or an innovative partnership approach that takes on board the experience and competence of all parties involved from the very first moment. The next in the chain, the EPC contractor, is also not able to realize 50% cost savings if sub-suppliers do not contribute to this, and if all sub-suppliers had not passed these savings on to their respective customers in form of reduced prices on their scope of supply and services. Finally, one of the levers is to reduce supplier tiers from five or more to three or less by applying cooperation agreements.

There are success factors and reasons for failure that follow a larger pattern, and the goal of this research was to capture and evaluate these factors, and to give structure to the overall pattern in a holistic approach. The model used was a holistic model for business transformation covering four success-critical dimensions, "People," "Organization," "Processes & Methods," and "Technology."

The basic principle of this model is the experience that any business transformation needs to happen balanced across all four dimensions. Initiatives that limit the effort to cover one or two of these dimensions will fail if the other dimensions are neglected. Therefore, recommendations are assembled comprehensively, with digitalization as the leading (and potentially disruptive) technology foundation. On this foundation, we define four pillars of organizational and process/methods-related changes, covered by the roof of human behavioral changes—the people dimension and ultimately the most challenging part of all.

Digitalization is the foundation. Ten years ago, most experts would have agreed to the thesis that we should first define the processes and then select and define the corresponding IT solutions. In the age of Industry 4.0, we recognize that IT is developing new solutions and new opportunities at a speed that our business processes are hardly capable of following. We are too slow in evolving our business processes to give them the lead; digitalization is the driver that imposes changes, sometimes disruption on traditional business models. In other industries, this is already a reality, and we should not exclude the same happening in the future in the EPC of industrial plants. The title of the initiative "EPC 4.0" references Industry 4.0 as a "fourth" industrial revolution driven by (software) releases.

The research team has identified four major fields of action to address changes in organization and in processes and methods, which are all linked to each other:

Collaboration by partnership makes reference to the public infrastructure sector, suggesting specifically that investors/owners/operators consider contractual models different from the traditional EPC LSTK approach, such as alliance contracts or lean integrated project delivery models (Cheng et al. 2019).

Flat supply chain references examples of supply chain integration from the aviation and automotive industry, suggesting partnerships with strategic suppliers that go beyond the capital project horizon and into the field of operation and maintenance.

Flexible organization advocates standardization of project management, EPC processes, as well as standardization in qualifications to enable the EPC business to adjust flexibly to business cycles with organization structures scalable to market needs.

Focus on core competences finally suggests that all participants share work scope and associated risks with the party who is best capable and competent in managing these. This focus releases resources for urgently required innovations: innovations in plant technology, such as modularization, innovation in state-of-the-art information technology to increase productivity and reduce nonconformance and underperformance costs.

5.1 The human factor

All these changes will not be successful without the support of the people working in our industry. The magnitude of changes triggered by Industry 4.0, in organizations, in processes and methods, requires a transformation program driving a cultural change in the behavior of our human resources. There are well-established tools and methods to guide organizations,

companies, or project teams to work towards a change in attitude and mindset.

A reduction of up to 50% of CAPEX? What at first glance may look like utopia may not be impossible if broken down into smaller elements where we are wasting money in our capital projects today. Planned CAPEX and the as-built CAPEX in reality differ significantly—the cost overspend in megaprojects ranges between 30 and 50% on average!

But even when analyzing the planned CAPEX: the cost of lost productivity, transaction costs that do not add value, such as the costs of mark-up fees, the cost of duplicating project organizations for project governance, the cost of bidding, the cost of claiming and penalties, the cost of risk contingencies in CAPEX... All in all, we conclude that up to 50% of the money we spend on capital projects is avoidable and does not contribute to the value of the assets we build.

The following example is not aimed at proving the feasibility of saving up to 50% CAPEX. The savings potential is limited by the nature of the business case, market conditions, owner's structure, region of project execution and operation, and many other factors that impact the cost breakdown of CAPEX. However, it invites investors, owners, and contractors to explore the savings potential for their specific business cases if the measures described in this report are implemented successfully.

With the random example, a CAPEX cost breakdown is provided, with a 13% share of the owner's costs, and an 87% share of what in an LSTK setup would be the EPC contractor's share. We are aware that some projects come with owner's costs as low as 10%, while in others, the owner's costs make up a share of up to 30%. Costs of engineering can vary in a range from as low as 5% to as high as 30%, depending on the degree of engineering reuse and depending on the location of the engineering team in a high- or low-salary region. The share of construction costs, specifically construction labor, may be significantly higher if the project is executed in a high-cost region, for example, the US or Northern Europe. The share of equipment and (bulk) material costs depends on the technology of the plant. Consequently, the figures below are not representative of "EPC projects" in general, as they can illustrate one dedicated example only.

In the calculation presented in Table 1, the cost breakdown can be read as absolute figures, representing a project with a total budget of 100 Mio EUR, or as a percentage. The individual savings are multiplied to determine the total saving, and it is important to understand that the levers in each saving category must be different and independent from each other. In this example, we have identified four major (and independent) levers to achieve savings: team integration, productivity, transaction costs, and schedule acceleration.

Tab. 1: Example of the cost breakdown for an EPC project with potential savings

Cost Element	Cost Breakdown before savings	Team integration	Productivity	Transaction costs	Schedule accel.	**Total Savings**	**Cost Breakdown after savings**
Owner	13	50%	30%		20%	**72%**	**4**
Project Management	6	50%	30%		20%	**72%**	**2**
Construction & Start-Up Management	8	50%	30%	10%	20%	**73%**	**2**
Engineering	14		30%		20%	**44%**	**8**
Equipment	21		30%	10%		**37%**	**13**
Bulk Materials	11			10%		**10%**	**10**
Construction Labor	12		30%	10%	20%	**50%**	**6**
Other Construction Costs (e.g. site logist.)	2			10%	20%	**28%**	**1**
Contingency	6			50%		**50%**	**3**
Special Costs (Legal, Travel etc)	7			80%		**80%**	**1**
	100						**50**

5.1.1 Team integration

The total number of personnel involved in the management, supervision and governance of the project, traditionally (more than) duplicated in parallel project organizations for the owner, for the EPC contractor, for the construction company and lower-tier subcontractors may be halved just by forming integrated teams based on contractual schemes supporting partnership.

5.1.2 Productivity

Exploiting the full potential of digitalization, such as BIM or automation in construction management, the reduction of claims and claims defense, the integration of suppliers and the early involvement of all parties may lead to a significant increase of the productivity of owner's management, project management and construction and start-up management up to 30%. Possible productivity gains in engineering, in the manufacture of equipment and construction (labor productivity) in the range of up to 30% may be achieved through the reduction of waiting times, reduction of charges, and higher professionalism in coordination and supervision. These savings are still conservative compared to the overall productivity gap between the construction industry and other sectors of 30–80%.

5.1.3 Transaction costs

Reducing transaction costs (that according to CII may sum up to 40% of the project costs) is a significant lever. We point to the fact that duplication of project organizations for governance or reduction of claims are also transactional costs, but not considered here. In the example an additional reduction of up to 10% may be achieved by flattening the contracting pyramid, eliminating double markups in equipment supply and construction (management, labor, bulk material, and site logistics). Another major factor is the reduction of (double) risk contingencies by half across all levels of tier organizations from a total of up to 7–8% down to a range of 3–4%.

Finally, the category "special costs" includes positions such as traveling, but to a significant share also legal costs (in some projects up to 10%!) or other costs that are associated with defending contractual positions which do not add value to the overall project. Applying the partnership approach in contracting may eliminate up to 80% of these special costs.

5.1.4 Schedule acceleration

McKinsey determined an average of 53% schedule overrun on megaprojects (McKinsey 2017a), and the executing contractors consider this experience to a certain degree in their project schedules. While this research highlights the potential saving in terms of cost (CAPEX), the same levers (such as digitalization, collaboration, productivity gains, etc.) will also translate into shorter project execution times. A reduction of 20% in overall project duration and construction duration, as considered in the example, will directly reduce the time-dependent cost positions, for example, owner, project management, engineering, and construction costs (management, labor, and site logistics).

The example shall illustrate the potential impact of the different levers identified and described in this research to a sample cost breakdown. In this specific example, if we consider a CAPEX of 100 Mio EUR before savings, the aggregation of all potential savings will drive CAPEX down to 50 Mio EUR after savings, a reduction by 50%!

Overall, the saving potential in CAPEX may be in a range of 30–50% of the planned costs, and this potential does not include the elimination of nonconformance costs, as these costs never enter a budget but only will result in cost overspend. Just to recall: McKinsey [McKinsey 2017a] determined an average of 37% cost overrun on megaprojects.

Finally, it must be mentioned that the recommendations given in this research, such as supplier integration, operations readiness, or predictive maintenance, shall also help to drive OPEX down. Finally, the improvements in CAPEX and OPEX will result in a significantly better financial model for the business case, leading to better financing conditions, higher margins, and finally an attractiveness for investors that can compete with other industries.

Now it's up to the decision-makers of the EPC industry to simply start changing the business. The ones who succeed will be the leaders of tomorrow in EPC business. A faster way of improving the business is to analyze what other industries, sectors, and firms are doing and to apply lessons learned. There is no "silver bullet" to tackle the situation in EPC business. However, it's insightful to see how EPC is applied in other sectors and how industries, such as automotive and aerospace, are improving productivity, applying new (digital) technologies, and performing agile and collaborative practices.

References

Barshop, P. (2016). *Capital Projects – What Every Executive Needs to know to Avoid Costly Mistakes and Make Major Investments Pay Off*. Wiley, Hoboken.

BCG. (2016). *Shaping the Future of Construction – A Breakthrough in Mindset and Technology*. Available at https://www.bcg.com/de-de/publications/2016/shaping-the-future-of-construction.aspx [accessed 25 December, 2019].

Cheng, R., Osburn, L., & Lee, L. (eds.). (2019). *Integrated Project Delivery: An Action Guide for Leaders*. Integrated Project Delivery Alliance (IPDA), San Bernadino.

CII. (2018). *Finance and Accounting Isn't for Cavemen*. Available at https://www.construction-institute.org/blog/2018/february-2018/finance-and-accounting-isn-t-for-cavemen [accessed 25 December, 2019].

CURT. (2018). *Operating System 2.0 Summary Brochure*. Available at https://www.curt.org/wp-content/uploads/2018/02/OS2-Summary-Brochure.pdf [accessed 25 December, 2019].

d1g1tal AGENDA. (2018). *Rethinking How Capital Programmes can be Delivered*. Available at https://www.economic-plant.com/issuebrowser/d1g1tal_agenda_capital_projects_2018_3/html5/index.html?&locale=DEU&pn=5 [accessed 25 December, 2019].

ECI. (2018). *Rethinking How Capital Programmes are Delivered*. Available at http://www.eci-online.org/news/rethinking-how-capital-programmes-are-delivered-report-of-the-eci-conference-on-3rd-october-2018/ [accessed 8 November, 2019].

Flyvbjerg, B. (ed.). (2017). *The Oxford Handbook of Mega Project Management*. Oxford University Press, Oxford.

Global Construction. (2015). *Report "Global Construction 2030" – Global Construction Perspectives*. Available at https://www.globalconstruction2030.com/ [accessed 25 December, 2019].

Koschke, A. (2019). *How Does the Agility Trend Affect Project Management?* Tiba Managementberatung, Munich.

McKinsey. (2017a). *The Art of Project Leadership: Delivering the World's Largest Projects*. Available at https://www.mckinsey.com/industries/capital-projects-and-infrastructure/our-insights/the-art-of-project-leadership-delivering-the-worlds-largest-projects [accessed 25 December, 2019].

McKinsey. (2017b). *Competing in A World of Sectors without Borders*. Available at https://www.mckinsey.com/business-functions/mckinsey-analytics/our-insights/competing-in-a-world-of-sectors-without-borders?reload [accessed 25 December, 2019].

McKinsey. (2017c). *Reinventing Construction: A Route to Higher Productivity*. Available at https://www.mckinsey.com/~/media/mckinsey/industries/capital%20projects%20and%20infrastructure/our%20insights/reinventing%20construction%20through%20a%20productivity%20revolution/mgi-reinventing-construction-executive-summary.ashx [accessed 25 December, 2019].

Riemensperger, F., Hagemeier, W., Pfannes, P., Wahrendorff, M., & Feldmann, M. (2015). *TOP 500 Studie Digitalisierungsgrad nach Branchen*. Accenture, Kronberg im Taunus.

Ritsche, F. P. (2017). *Time for Change – A vision for EPC 4.0 White Paper*. ProjectTeam, Düsseldorf.

Ritsche, F. P. (2019). *Project Management Handbook for EPC*, 2nd edn. ProjectTeam, Düsseldorf.

Ritsche, F.-P., Wagner, R., Schlemmer, P., Steinkamp, M., & Valnion, B. (2019). *Innovation Project EPC 4.0 – Unleashing the hidden potential – Final Report*. ProjectTeam, Düsseldorf.

VDMA. (2017a). *Proceedings of the VDMA Arbeitsgemeinschaft Großanlagenbau, Engineering Summit in Mannheim*, Germany, 2017. VDMA, Frankfurt.

VDMA. (2017b). *Potenziale von Industrie 4.0 im Großanlagenbau*. VDMA, Frankfurt.

Wagner, R. (2019). *EPC-Projects, A Class of its Own*. Available at https://www.ipma.world/epc-projects-class/ [accessed 25 December, 2019].

Worldbank. (2018). *Commodity Markets Outlook*. Available at https://www.worldbank.org/commodities [accessed 8 November, 2019].