

► The Future of Construction Machinery Manufacturers

Ecosystem with a new perspective

INSIGHTS

//01

The provision of affordable housing is one of the greatest challenges facing society today, and one that is being intensified by the constant population growth.

//02

In comparison with other industries, the construction sector has a poor track record in productivity growth.

//03

Digitalization and robotics will revolutionize the construction ecosystem.

//04

Construction machinery manufacturers are well positioned to take a leading role by changing from pure hardware manufacturers to system suppliers in a fully connected construction ecosystem.

The Future of Construction Machinery Manufacturers

Ecosystem with a new perspective

In 2019 the construction industry spent US\$11.4 trillion and therefore makes a significant contribution to the world's overall economic development.¹ The industry is also a key factor in creating an environment that satisfies the need for reasonably priced housing and corporate buildings as well as large-scale infrastructure.² In addition, the industry can and must contribute to a more sustainable environment by further reducing its CO₂ emissions. Hence, this industry is one of the most important enablers for the ongoing urbanization and a relevant lever in addressing climate change.

At the same time, the industry is facing external conditions that are changing in entirely new ways. In particular, forces in politics and society are pushing for lower emissions and more resource-friendly construction sites. Rising demand for buildings and infrastructure has become one of the greatest challenges of our time, especially given the stagnating productivity levels of construction sites (+4% from 1991 until 2018).³ This puts the construction industry under pressure to find appropriate answers. And whoever finds the best answers to these challenges might gain a competitive advantage on the market.

This race for a competitive edge even becomes business-critical for construction machinery manufacturers, as certain areas of the construction industry are predicted to shrink in the years to come, including construction equipment (worldwide sales forecast: -4% from 2018 until 2023).⁴ And this forecast does not take into consideration the economic impact of the global COVID-19 crisis, which will have negative consequences on the construction industry as well. Current estimates show that factory closures and national lockdowns around the world will cost the global construction equipment industry a loss in production totaling 43,000 machines this year, which translates into 4% of 2019's output.⁵

¹ "Construction industry spending worldwide from 2014 to 2025," Statista, accessed July 2, 2020, <https://www.statista.com/statistics/788128/construction-spending-worldwide/>.

² "Volkswirtschaftliche Gesamtrechnungen: Inlandsproduktsberechnung 2019," Statistisches Bundesamt, January 15, 2020, <https://www.destatis.de/DE/Themen/Wirtschaft/Volkswirtschaftliche-Gesamtrechnungen-Inlandsprodukt/Publikationen/Downloads-Inlandsprodukt/inlandsprodukt-erste-ergebnisse-pdf-2180110.html>.

³ See Statistisches Bundesamt, Institut für Arbeitsmarkt- und Berufsforschung (IAB) der Bundesagentur für Arbeit (BA), Nuremberg, 2018.

⁴ Off-Highway Research, "Off-Highway Research forecasts continued high in global construction equipment sales," Lectura Press, February 11, 2019, <https://lectura.press/en/article/off-highway-research-forecasts-continued-high-in-global-construction-equipment-sales/45576>.

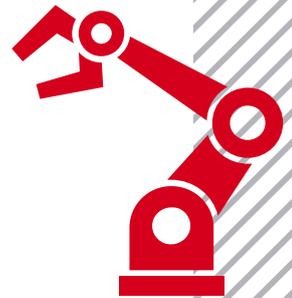
⁵ Chris Sleight, "Covid-19 to wipe 4% off global construction equipment production," Off-Highway Research, April 6, 2020, <https://offhighwayresearch.com/News/Covid-19-to-wipe-4-per-cent-off-global-construction-equipment-production/279.article>.

That being said, innovative technologies are guiding the industry into a new era, leading to disruptive changes in the industry. The digital transformation in the construction machinery industry is about to start and will disrupt this industry, as it has other industries many times before. This transformation will lead to new business opportunities for all players in the field of construction and will push the boundaries of existing business models to a new level. It will be the enabler to find answers to some of the most crucial challenges within the industry, and within our society as a whole.

A Porsche Consulting survey on the future development of construction machinery manufacturers forms the cornerstone of this strategy paper.⁶ Participants from construction-related industries shared their professional opinion on this topic. Hence, this paper offers an outlook on the ecosystem of construction machinery manufacturers and the ways new business opportunities can develop from there.

Construction machinery manufacturers*

are defined as companies that manufacture stationary or mobile machines powered by combustion engines or electric motors. They are used for processing and machining building materials, transporting accessory materials, and performing construction tasks.



* Industry sectors 28.29.1, 28.22.0, and 29.10.2 in accordance with the definition of the German Federal Office for Statistics

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Figure 1. Definition of the construction machinery manufacturing industry

KEY MESSAGES

▶ 01

Construction machinery manufacturers are one of the key players that stand to gain an advantage from this ecosystem and can develop new business opportunities in the years to come.

▶ 02

To be on the winning side and gain a competitive advantage, construction machinery manufacturers need to engage in new trends and technologies and translate them into innovative business models.

⁶ Porsche Consulting's survey "The Future of Construction Machinery Manufacturers" queried 18 participants from the five industries of construction, commercial vehicles, construction machinery, industrial supplies, and universities in February 2020.

Changing Framework Conditions in the Construction Industry

In a Porsche Consulting survey 85% of the participants agreed that the construction machinery industry is currently facing tremendous changes. Two main factors are considered the drivers for the changing external conditions: society, politics, and regulations.

DRIVERS



Society

//Need for affordable housing and high performance infrastructure



Politics & Regulation

//Need for more sustainable construction sites

Figure 2. Drivers of changing external conditions for construction machinery manufacturers



Society

In a so-called medium-growth scenario, global population is expected to grow from 7.7 billion in 2019 to 9.7 billion in 2050.⁷ Hence, significant growth in demand can be expected in two relevant areas:

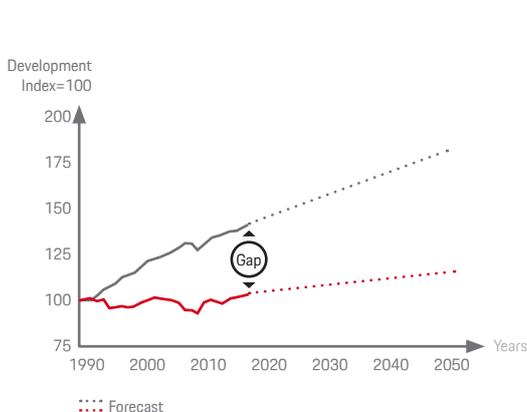
- ▶ **affordable housing and corporate buildings**
- ▶ **large-scale infrastructure projects**

Population growth is not the only factor in increasing demand for affordable housing. Changing demographics due to an aging population and the growing number of single and two-person households will also lead to a disproportionate increase in housing demand. This will result in the need for an additional 1.6 billion homes over the next 30 years.⁸

The sheer rise in population will drive demand for high-performance infrastructure in public transport and freight logistics. More people need to be supplied with more essentials in limited urban space. Therefore, the complexity of infrastructure solutions will continue to increase in future. A total of 87% of survey participants see the rising number of infrastructure projects as a major factor that will influence the construction machinery industry in the years to come.

Both aspects—global population growth and increasing demand for high-performance infrastructure—affect an industry with one of the lowest productivity levels. Regarding the volume of work, the price-adjusted productivity increase per hour of employment grew across all economic sectors on average by 44% in the period from 1991 to 2018.⁹ At the same time, the productivity level in the construction industry grew by just 4%, which essentially reflects a stagnation. Low productivity in construction is the result of a multitude of factors. But studies have shown that it primarily comes down to underinvestment in (IT) technology, lack of prefabrication and standardization as well as overall poor collaboration within the supply chain.¹⁰

This situation will create a gap between the demand for housing and corporate buildings and the supply capabilities of the construction industry. Aiming for higher productivity within the construction machinery industry is a prerequisite to fulfilling the increasing demand of a growing society and to gaining a competitive advantage in the construction industry by realizing additional revenues at the same time.



Demand

- ▶ Population growth up to 8.5 bn people in 2030 and 9.7 bn people in 2050
- ▶ Infrastructure projects due to increase in urbanization (6.6 bn people will live in cities by 2050)

Supply

- ▶ Stagnating productivity level of construction in recent years

Gap

- ▶ Increase in productivity is necessary to meet future demand in housing and infrastructure projects
- ▶ Otherwise demand will increase disproportionately to supply

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Figure 3. Productivity gap between supply and demand in the construction industry (development from 2015 onwards based on avg. compound annual growth rate)

⁷ "World Population Prospects 2019," United Nations, accessed July 2, 2020, <https://population.un.org/wpp/>.

⁸ Sean Smith, "The world needs to build more than 2 billion new homes over the next 80 years" The Conversation, February 28, 2018, <https://theconversation.com/the-world-needs-to-build-more-than-two-billion-new-homes-over-the-next-80-years-91794>.

⁹ See Statistisches Bundesamt, Institut für Arbeitsmarkt- und Berufsforschung (IAB) der Bundesagentur für Arbeit (BA), Nuremberg, 2018.

¹⁰ Jonathan Woetzel, Mukund Sridhar, and Jan Mischke, "Opinion: The construction industry has a productivity problem," MarketWatch, March 6, 2017, <https://www.marketwatch.com/story/the-construction-industry-has-a-productivity-problem-and-heres-how-to-solve-it-2017-03-04>.



Politics & Regulation

The trend in urbanization will result in 68% of the world population, or 6.6 billion people, living in urban regions by 2050.¹¹ Consequently, the aforementioned housing demand will not be evenly distributed across the world but instead focus on preexisting and newly emerging metropolitan areas. In times of omnipresent discourse on climate change and emission reduction, regulatory measures are taken to reduce the global climate impact of construction activity and to increase urban livability by mitigating local pollutants and noise emissions. Many regional administrations have therefore drafted local ordinances on particulate, CO₂, and noise emissions of construction equipment used in public projects. Additionally, an increasing number of countries have begun putting price tags on CO₂ emissions. The survey reveals that 90% of companies in the construction machinery industry expect CO₂ regulations to have an impact on construction machinery manufacturers. Like automotive OEMs, these companies are searching for alternative energy sources to reduce or totally eliminate CO₂ emissions on construction sites. Hydrogen, fuel cells, synthetic fuel and e-mobility solutions are on the agenda of innovative market players. But the challenges are the same as those of the automotive industry.

Electric batteries in particular need to handle the steep and fast increase in energy that a construction machine requires when lifting heavy weights. This puts the electric batteries under enormous stress and currently leads to a technological limitation on construction sites. As a result, this altered external condition is on the agenda of most companies, but solutions are not yet at a maturity level to offer answers easily.

The changing external conditions are certainly not exhaustive and can be widely extended with regard to different aspects. Whatever factors may be taken into consideration, two conclusions are drawn. The construction machinery industry will undergo tremendous changes based on the need to:

- ▶ **increase productivity to fulfill future demand and ensure market competitiveness**
- ▶ **reduce its CO₂ footprint to comply with regulations and customer expectations**

Future Ecosystem for Construction Machinery Manufacturers

Robert Dietz, chief economist for the National Association of Home Builders, has foreseen that COVID-19 will cause a substantial economic downturn in the USA that may also be short.¹² In the second quarter of 2020, the GDP growth will be significantly negative in the USA and most likely the country's worst performance since the fall of Lehman Brothers back in 2008. A weak third quarter will likely be followed by a rebound at the end of 2020. So the construction industry is expected to once

again face high demand and high utilization for the post-COVID-19 era. The order books have been full for years, and customers are used to long project-lead times. In any case, taking this situation for granted might be the beginning of the end for some players on the market, as seen in the past with Kodak, Nokia, and the mail-order company Quelle.

¹¹ "World Urbanization Prospects: 2018 Revision," United Nations, accessed July 2, 2020, <https://population.un.org/wup/>.

¹² "COVID-19's impact on the construction industry," EC&M, March 23, 2020, <https://www.ecmweb.com/covid-19/article/21126812/covid19s-impact-on-the-construction-industry>.

Taking into consideration existing challenges and current technological developments, it seems inevitable that the ecosystem for construction machinery manufacturers will change drastically in the next couple of years. Companies that are going to leverage new opportunities offered by this ecosystem will gain a competitive advantage and strengthen their market position. Other more reluctant players might find themselves in a weaker market position in new ecosystems. But how will this new ecosystem look? What are its characteristics? And which fields can possibly be occupied by construction machinery manufacturers in the future?

Figure 4 highlights various uses cases within the construction site of tomorrow, which will be:

- ▶ **connected and autonomous**
- ▶ **more productive**
- ▶ **more sustainable**



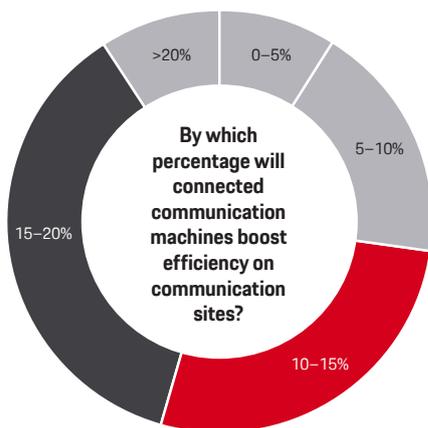
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Figure 4. The future ecosystem of construction machinery manufacturers

The prerequisite for most of the use cases depicted in the figure is a consistent connectivity between all relevant devices on the construction site. Below we take a detailed look on the four most promising use cases and their potential business model impact for construction machinery manufacturers.

► Connected and autonomous construction machinery

In the automotive sector as well as in industrial production, connected machines and related services have become increasingly important. Sensors and network communication equipment are small and cheap enough to be built into every controller unit of future machines. 80% of survey participants assume that connected construction machines could boost the efficiency on construction sites by 10 to 20%.



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Figure 5. Porsche Consulting survey: efficiency boost by connected construction machines

Connected construction machines of both building and heavy machinery offer several benefits for users and manufacturers. These benefits can be bundled to new service offerings and business models. In the future, fleets might be fully equipped with sensors for position tracking and gathering machine data, such as power consumption, temperature, acceleration, and vibration. Fleet operators will track and manage their fleets remotely using online service platforms, while manufacturers analyze billions of data points with AI for predictive maintenance service, repairing the machine even before it breaks down. This increases productivity, as waiting times for repair service or new machines are avoided. These kinds of digitally supported services have the potential to generate additional revenue streams for the

construction machinery manufacturers in the coming years, beyond just selling, renting, or maintaining machines.

Not only traditional players but startups, like the German company CORRUX, are developing AI-based solutions, enabling predictive maintenance business models and increasing construction productivity.¹³ In the medium term, digital services will become mandatory to compete within the industry. Customers will not be willing to pay for these in the future once the first manufacturer offers the services free of charge. This will require construction machinery manufacturers to think about their revenue streams and cost structure. One strategy is to integrate digital services in the machines instead of offering them separately and charge the customer for machine usage instead of selling.

TOP 3 measures for leveraging emerging digital opportunities for construction machinery manufacturers:

- 01 Digitalization of business processes for more flexible business operations with faster reaction times
- 02 Development of modular product architecture as a prerequisite for seamless integration of digital solutions, which can be applied across products
- 03 Investment in digital ecosystem (e.g. by enhancing company portfolio with digital start ups)

Digitalization is a prerequisite for these new business models. 75% of survey participants see more opportunities than challenges in the digitalization of their construction machin-

¹³ See CORRUX GmbH, www.corrux.io.

ery company. Most of the companies are aware of the emerging digital opportunities and potential business models, a fact confirmed by 65% of participants. And yet, 65% do not think that their company is entirely on track with digital transformation to be able to benefit from these opportunities.

In the medium term, another innovation will greatly impact the construction industry: autonomous machine operation based on machine-to-machine communication. Connected construction machines communicating with each other enable autonomous working applications, which will further increase productivity of the resources used. As with production plants, communicating construction machines can interact with

each other and proactively steer the construction processes along the value stream on-site. Cranes or concrete pumps will automatically steer their just-in-time supply processes and request new material depending on the current work progress. Mining excavators and trucks will communicate their payloads and material properties to the processing equipment along the value chain. By offering these services to their customers, construction machine manufacturers will create additional value by increasing their customers' productivity.

Machine-to-machine communication is also a prerequisite for the next innovative use case: construction robots.

► Construction robots

Industrial robots have shaped the production industry over the last 50 years. The high efficiency and fully autonomous operations have especially revolutionized the automotive industry. Every modern production factory, including construction machine manufacturers, uses industrial robots for welding and assembly operations, painting, material supply, and other processes. However, one use case for robots has barely been developed: the construction of buildings.

The reason for this lies in several challenges: individual layouts for each building lower the potential for standardization, while reduced infrastructure and rough ambient conditions on construction sites present a difficult environment for automated work. Additionally, workplace safety regulations might have been an obstacle for the joint work of workers and autonomous robots in the past. Nevertheless, with today's sensor technologies like laser scanners or camera systems, robots will be able to securely navigate construction sites and within buildings, possibly supported by workers, other machines, and tools—all communicating with each other. A prerequisite for robot applications and collaboration is a commonly used construction data model. Building information modeling (BIM) is a method for connecting all of the various stakeholders involved in the construction site and sharing data like 3D CAD building models, construction schedules, or even real-time supply-chain information, such as delivery times for concrete and other supplies.¹⁴

Successful usage of construction robots is expected in two steps:

- 01** Application of robots for standardized building of modules in production lines. This is already being developed and tested by several players in the construction sector today, such as ADMARES or Katerra.
- 02** Application of robots on the construction site for assembling modules to construct the actual building including walls, ceilings, and stairs. This module assembly will be supported by further robots for bricklaying, attaching steel reinforcements, injecting concrete, or 3D printers, while enabling communication with other machines. In addition to building construction, this is applicable for infrastructure projects with recurring tasks, such as road or rail construction, and is exemplified by the ROBEL Track Construction Robot.¹⁵

¹⁴ For further details on BIM, see Porsche Consulting, "The Future of Construction Machinery Manufacturers: Ecosystem with a new perspective", <https://www.porsche-consulting.com/en/press/insights/detail/white-paper-building-information-modeling/>

¹⁵ "Track Construction Robot," ROBEL Bahnbaumaschinen, accessed July 2, 2020, <https://www.robel.com/en/systems-vehicles/workshop-on-wheels/track-construction-robot/>.

Due to the fact that this market segment is yet to be developed, construction machinery manufacturers have the chance to enter the robotics sector and be able to offer their customers innovative solutions, increasing productivity and reducing costs on construction sites. Entering this market can be realized by collaborating with established industrial robot manufacturers like KUKA, ABB, or Fanuc to develop flexible construction robot cells for specific requirements. To enable sustainable success and seamless integration of robots in the construction environment, a machine-to-machine communication platform will be required to enable robots to communicate with other machines along the value chain. Modular management will be a key enabler for the success of

robotics in the construction machinery industry. As with the automotive industry, robots can leverage their potential when their tasks are within a modular environment. This modular approach can be transferred to construction modules and the flexible design of the robot cells themselves.

And the future is now. Disruption is ongoing because initial prototypes of fully autonomous bricklaying robots are successfully building 180 square-meter houses with three bedrooms and two bathrooms, as the manufacturer FBR's Hadrian X robot has proven.¹⁶ These prototypes have been developed by startups disrupting the industry, instead of by traditional construction machine manufacturers.

▶ 3D printing of buildings

Another new robotic technology with high development potential for construction machinery manufacturers is 3D printing. The intended focus relies on construction machinery manufacturers becoming an OEM for 3D printers for buildings, or at least building modules. The 3D printing of buildings has been in the prototype phase for several years. Universities, startups, and even traditional construction machinery players, like concrete pump manufacturers, are developing

3D-printing robots that can print buildings with minimal human involvement. In 2019 the world's largest 3D-printed building, covering 640 square meters, was successfully built in Dubai—by just one Apis Cor printer and three workers.¹⁷ Printing complete buildings might stay a niche market, but the application of 3D printers for prefabrication of building modules, together with other construction robots, is an interesting use case.

▶ Electrification of construction machinery

In light of increasing regulations on CO₂ or noise emissions, the integration of electrified construction machinery into the manufacturer's product portfolio can be both a chance for additional revenue and a must-have to avoid penalties. The automotive industry is already facing strongly regulated CO₂ emission targets for their fleets. Japan, the United States, and Canada introduced new regulations on the CO₂ emissions of heavy-duty vehicles in 2014, after which the European Commission defined the extension of similar CO₂ emission regulations to heavy-duty vehicles like construction machinery as a strategic option.¹⁸ The latest European emission regulation, issued in 2016 and known as "Stage V," must be implemented in all newly produced heavy-duty vehicles with propulsion engine, including construction machines between 2019 and 2021, depending on their power.¹⁹ In the medium term, manufacturers will need to embrace electrification to maintain operation of construction machinery in urban regions. Besides just complying with regulations, the electrification

also offers construction machinery operators such benefits as reduced fuel consumption by electro-hydraulic systems, making machines more cost efficient. Replacing combustion engines with electric power trains not only requires construction machinery manufacturers to undertake considerable development and investments but also has implications on their business models. Electric power trains consist of less parts and require less maintenance than combustion engines. This means decreasing revenues generated through service contracts. On the other hand, battery electric machines present opportunities for new business models, such as the battery rental or charging contracts established in the forklift industry. This trend toward electrification will require construction machinery manufacturers to act, such as partnering with battery companies on the development of electric power trains and battery systems. As a consequence internal processes like product creation as well as the organizational structure might change due to changing core capabilities.

¹⁶ "Robotic construction is here," FBR Ltd, accessed July 2, 2020, <https://www.fbr.com.au/view/hadrian-x>.

¹⁷ "Collaborative Project with Dubai Municipality," Apis Cor, October 25, 2019, <https://www.apis-cor.com/dubai-project>.

¹⁸ Strategy for reducing Heavy-Duty Vehicles' fuel consumption and CO₂ emissions (COM [2014] 285), European Commission, May 21, 2014, <https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52014DC0285&from=EN>.

¹⁹ Regulation (EU) 2016/1628, European Parliament, September 14, 2016, <https://eur-lex.europa.eu/eli/reg/2016/1628/oj>.

Trends in the construction industry



Connected and autonomous construction machinery

and construction robots will significantly contribute to closing the lack of required qualified workers in the industry



Construction robots

will be common on construction sites as a way to increase efficiency and safety



3D-printing of buildings

will create new business opportunities for construction machinery manufacturers



Electrification of construction machinery

is one of the most relevant growth segments for construction machinery manufacturers



Telematics-based fleet management

will create new business opportunities



Predictive maintenance of construction machines

will have a significant impact on efficiency of construction machines



Drones

will be an integral part of future construction sites (e.g., property surveying, construction measurement, ...)

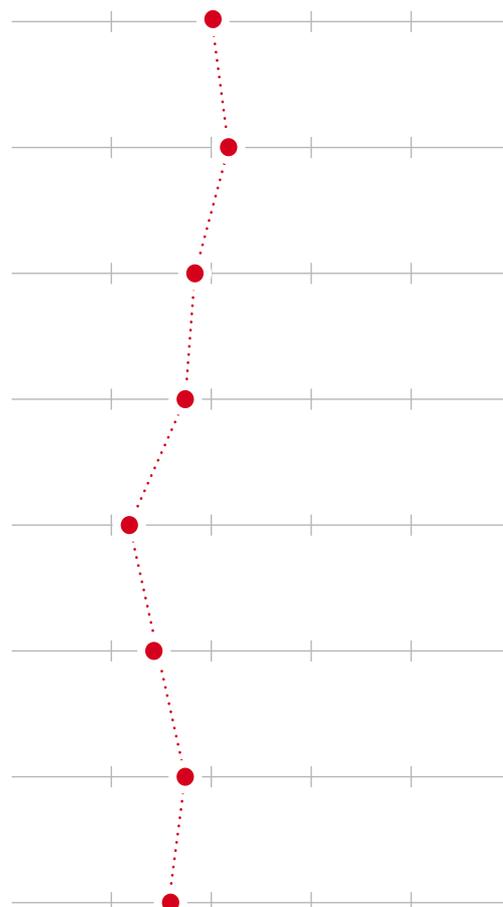


Indoor mapping

will be a key element to enhance customer experience and improve the planning quality for construction sites

◀ agree

disagree ▶



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Figure 6. Porsche Consulting survey: trends in the construction industry

Business Model Transformation of Construction Machinery Manufacturers

Eight out of ten decision makers in the industry expect that new business opportunities will arise for construction machinery manufacturers due to the digital transformation. In the “old world” the construction industry is operating on loose strings and with low productivity. Most stakeholders involved are planning and operating separately, leading to low productivity and delays in construction projects. The new ecosystem will be characterized by higher productivity, as new technologies in the described use cases replace the traditional way of working and increase speed of operations on-site. The biggest opportunity can be seen in a connected ecosystem that is highly system-oriented, with automatically managed

interfaces. Construction machinery manufacturers need to change their business models from pure hardware manufacturer to a system supplier that is managing the interfaces in a fully connected ecosystem. The advantages are obvious: less fixed costs and the possibility to collect data on a major scale.

The precise timeframe for these upcoming changes and the exact shape of the future ecosystem can only be assumed. Despite these open questions, the most important task for the management of construction machinery manufacturers is to look ahead to make the right decision now.

FUNCTION
ORIENTATION

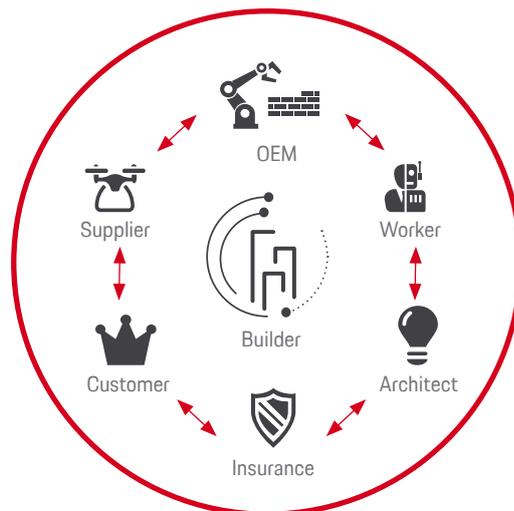
— **Old world**
Until early 2000
Analog construction industry on “loose strings”



— **New ecosystem**
2000–2025
Semi-digital construction industry with new solutions



— **Connected ecosystem**
Starting ~2025
Holistic interface management in construction ecosystem



ECOSYSTEM
ORIENTATION

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Figure 7. Ecosystem evolution of construction machinery manufacturers



IN BRIEF



-
- 01** The outlook for construction machinery manufactures exhibits similarities with other industries, such as the automotive sector. The shift from a purely hardware-focused business model to a facilitator of an ecosystem is trending.

 - 02** Use cases in the future ecosystem include connected and autonomous construction machinery, construction robots, 3D printing of buildings, electrification of construction machinery, AI-based resource allocation, drones for handling material and surveillance, driver-assistance systems, indoor mapping, and new business models like “power by the hour”.

 - 03** 80 % of survey participants expect connected construction machines to boost the efficiency of construction sites by ten to 20 %.

 - 04** At the same time, 65 % of participants do not think that their company is on track with their digital transformation to be able to benefit from these opportunities in the near future.

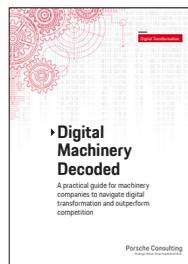
Further reading



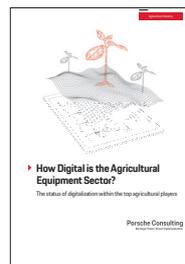
Top-Value Twin



Smart Building
as a Business



Digital Machinery
Decoded



How digital is the
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