McKinsey & Company

Public and Social Sector Practice

Road work ahead

The emerging revolution in the road construction industry

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Preface

Road networks, on which governments around the world spend significant shares of their civil engineering budgets, are rightly considered the lifeline for modern and successful economies. While those have been transformed by numerous innovations and (especially digital) disruptions, both the process and materials used in building roads as well as their key parameters and functionalities have remained remarkably unchanged over the past years and decades.

However, this seemingly natural continuity should definitely not lead to the assumption that there will be no major changes in the road construction industry in the future. It is already becoming apparent that four megatrends – autonomous driving, automated production, digitization, and advances in road construction materials – as well as a new process flow for road construction are bound to not only make the roads of the future look significantly different from those of today, but also make road construction much faster and cheaper.

Our aspiration in publishing this white paper is to provide objective insights into the various aspects posed by the emerging revolution in the road construction industry, its implications, and the pressing question of how to prepare for the shake-up of the industry landscape. The ideas and information in this article are the result of many months of work by numerous experts from McKinsey & Company and Oxford Global Projects. This paper should offer the latest and most relevant know-how on the status of road construction in Europe, current challenges, and an assessment of the potential of novel technologies and processes.

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Introduction and key messages

When thinking about innovation in transportation, roads will likely not come to mind first. Although construction materials and techniques have been improved incrementally, the basic formulation and construction of roads have remained largely unchanged over the past decades. As a consequence, questions concerning carbon-neutral powertrains, mobility ecosystems, and (semi-)autonomous driving dominate most discussions about the future of transportation, while road infrastructure plays a minor role in these debates, if one at all.

Until now, road networks have been given a back seat in discussions surrounding transportation – undeservedly so, given their importance. Private vehicles are the most common mode of transportation – accounting for more than 80 percent of traveled kilometers per passenger in the EU, for example – and road transport accounts for 75 percent of the total inland freight transport in the EU.[1,2] What is more, in almost all advanced economies globally, transportation continues to rely heavily on the ever-growing road network, which measures 6.2 million kilometers, just in the EU.[3]

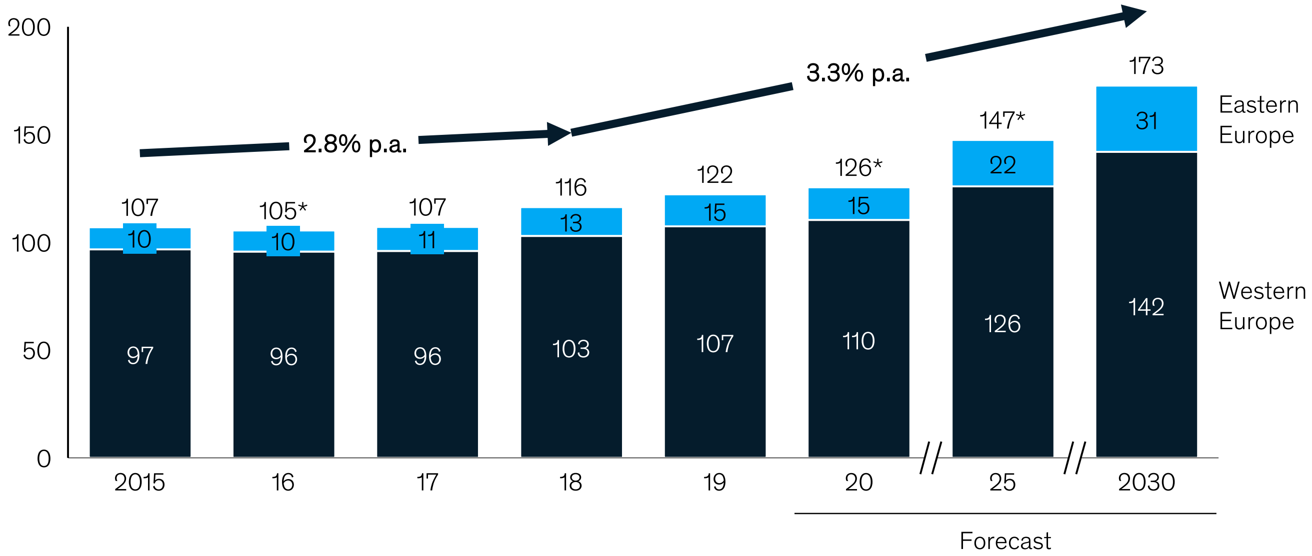
Reliable road networks thus help economies flourish, but they can equally curb further growth and prosperity if people and goods are caught up in traffic jams. Governments, therefore, spend significant shares of civil engineering budgets on road projects. European governments, for example, plan to spend over EUR 100 billion on road projects annually until 2030[4] (Exhibit 1) and are highly motivated, among other things, by the interests of their taxpayers to ensure that roads are built and upgraded cost-effectively while meeting the requirements of future transportation.

Exhibit 1

Road infrastructure investment in Europe is expected to accelerate

Road capex in Europe, historical and forecast

EUR billions



* May not sum due to rounding

Source: Euroconstruct 2018

Against this backdrop, this report provides fresh insights from the latest McKinsey research (Text box 1) into three pressing questions for the road construction industry and its stakeholders:

— How will contemporary megatrends, namely automation, digitization, as well as innovation in construction materials shape patterns in road transportation and construction?

— Why and in which ways will tools and processes in road construction need to change so as to facilitate the maximization of the benefits associated with these trends?

— What do these changes imply for the road construction industry's future and how can construction companies, public entities, and governments and their taxpayers prepare for this?

We will propose concrete steps for policymakers, road authorities, private developers/operators, and construction companies among which we hope to spark a debate about future technological and financial opportunities in road construction.

Text box 1: How we derived the insights of this report

A close collaboration between McKinsey & Company and Oxford Global Projects builds the backbone of this report. Over 18 months, scholars from both institutions worked together to examine how roads will be built in the future and what the implications for multiple stakeholders may be. In doing so:

— All important and most recent research/literature on road construction and design was reviewed as a starting point of the analyses.

— More than 30 experts were interviewed to understand current challenges and to assess the potential of novel technologies and processes.

— A proprietary Oxford Global Projects database on cost and schedule overruns for road construction projects and megaprojects was leveraged to identify, analyze, and understand the key drivers of speed and cost in road construction.

— Implications for policymakers, road authorities, private developers/operators, and construction companies were derived in close alignment with McKinsey's Public Sector Practice.

Our research and analyses yielded the following key insights that will be explained in more detail in this report:

— Four megatrends can be expected to strongly impact future road design and construction:
  - Once autonomous vehicles (AVs) reach a critical mass, road width may shrink by a third
  - Automation in road construction will increase productivity and profit margins
  - Digitization enables smart roads that improve lane capacity and increase road capabilities
  - Advances in construction materials increase road durability by 60 percent.

— Speed of road construction is expected to double, while costs may shrink by 30 percent if novel technologies and process optimization are applied consistently.

— New value pools and actors are likely to make road construction more competitive.

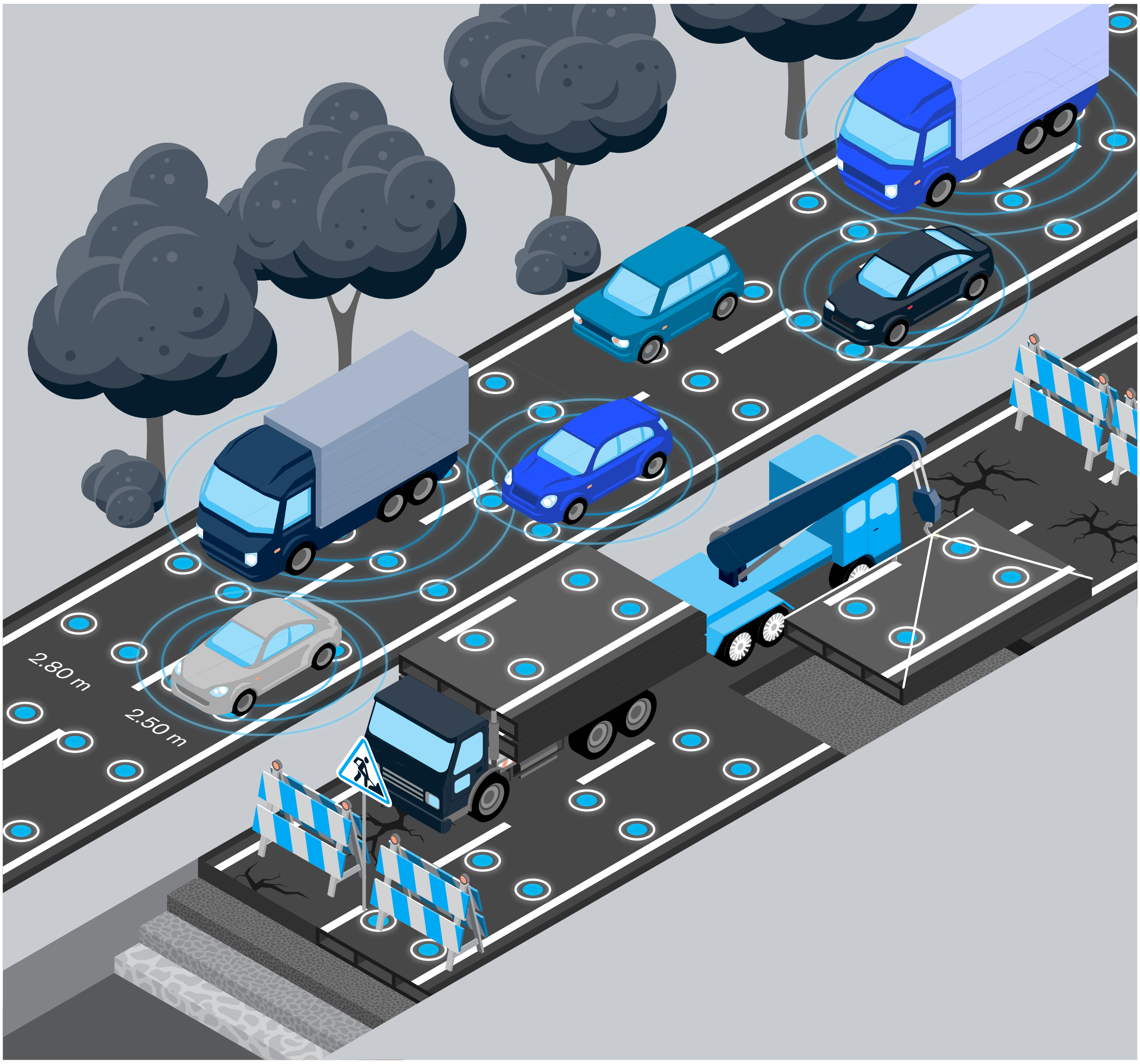
— To channel innovation and realize economic benefits, governments can seize the initiative and craft a broad alliance with relevant players from the private sector with a view to setting standards for smart roads.

Four megatrends can be expected to shape future road design and construction

The adage “the pace of change has never been this fast, yet it will never be this slow again,” commonly used to describe contemporary shifts in society, also holds true for the road industry, which is expected to change massively by 2050. Four major trends will propel this change: autonomous driving, automated production, digitization, and advances in road construction materials. With these megatrends at play, in 2050 at the latest, roads in the EU and countries such as the US, Canada, and China will be narrower, faster, less expensive to build, smarter, and more durable than today (see illustration). For players in this space, there are three main reasons why tomorrow’s revolution requires planning and attention today:

— **Long lead times.** Planning and creating the conditions for the construction of these new roads will have a long lead time – potentially more than 15 years.

— **Significant investment.** In many cases, these new features will require significant investment in brownfield upgrades of existing road infrastructure.



— **Staggered horizons.** Even though all megatrends are expected to have significant impact on road design and construction in the future, their timing might unfold differently. Advances in construction materials are imminent and yield gradual optimization potential. Digitization of roads will likely occur step-by-step as existing roads are upgraded and modularization in construction kicks in. By contrast, roads may only become narrower once a critical number of vehicles are fully autonomous.

Once AVs reach a critical mass, road width may shrink by a third

Availability and usage of autonomous capabilities is projected to increase rapidly in the not-too-distant future. By 2035, 15 percent of light vehicles sold globally can be expected to be equipped with fully autonomous capabilities, i.e., Level 4 or Level 5.[5,6] In advanced economies, this share is expected to be even higher. In a world where people no longer need a driver's license, and driverless trucks no longer require resting phases, vehicle kilometers are projected to increase substantially,[7] mainly for two reasons:

— **Higher transport efficiency.** Inefficiencies such as congestion delays and accidents currently cost EU countries an estimated 1 percent of their gross domestic product (GDP) per year.[8] The rise of AVs has the potential to significantly decrease these inefficiencies through accident-reducing technologies and driving techniques such as "platooning," a method for coupling vehicles and thus driving them closer together than previously possible.

— **Reduced mobility costs.** The spread of AVs is also expected to drive down mobility costs by increasing utilization by eliminating the need for resting phases (in the case of trucks). The practice of sharing vehicles on an as-needed basis could reduce mobility costs, i.e., the total cost of ownership of a regular car, from USD 0.85/mile (USD 0.53/kilometer) to USD 0.4 (USD 0.22/kilometer) by 2035.[9]

Autonomous driving guarantees unrivaled precision and reliability, which will eliminate the need for lanes that are much wider than vehicles. Whereas traditional lanes, usually with a width between 3.50 and 3.75 meters,[10] are devised to account for human error, the width of future lanes could be reduced to 2.8 meters and still accommodate oversized vehicles. Roads exclusively dedicated to passenger cars could have lanes as narrow as 2.5 meters. This means that a four-lane road could be up to 4 meters narrower than today.

In the case of newly constructed roads, narrower roads could see a decrease in required construction material of up to one-third. In the case of existing roads, narrower lanes will free up valuable space that could either be used to increase the capacity of existing roads by up to 50 percent (expanding a four-lane road to a six-lane road without the need for more space) or be dedicated to other transportation methods (e.g., pedestrian paths, bike lanes, bus lanes, tram tracks), particularly in cramped urban environments.

Generally speaking, high-level automation of vehicles and a higher adoption rate of AVs are key requirements for roads to be able to become narrower. Since there is currently no indication that any government is likely to limit highway usage to AVs, all will depend on the adoption rate. Here it is estimated that an adoption rate of at least 85 percent will be necessary to get the authorities to consider making a trade-off between economy-wide benefits and regulations restricting non-AVs for individual road users.

Automation in road construction will increase productivity and profit margins

Aside from AVs, automation will significantly impact road construction – primarily due to its chronically low productivity. Over a 20-year period, other industries such as retail and manufacturing have realized annual productivity improvements of 2.8 percent because they systematically reinvented themselves through automation and process-flow optimization. The construction industry has not yet tapped the potential from automation, which has resulted in an improvement of just 1 percent per year during the same period.[11]

Given the still comparatively large amount of manual labor needed to build a road, automation is a promising opportunity to improve productivity in this low-margin industry. Potential productivity improvements in road construction through automation are ample, yet few case studies have produced reliable results that would allow the effect of an end-to-end automated process to be quantified.

The initial surveying could be further automated through lidar technology, which could not only save money but also time. Data from multiple sources could be fed into a digital representation of the physical asset – a digital twin. Such digital models allow roads to be visualized across their entire lifecycle to optimize asset performance. 3-D machine control excavation systems may serve as a proxy to gauge the potential from automation in the later process. These systems combine geolocation services with digital models to partially automate earthworks. Excavators equipped with such systems can carry out excavations or grading up to 30 percent faster than machines without a 3-D system.[12] Finnish researchers have even built an automated 3-D blade control system that achieved a 100 percent increase in labor productivity while maintaining a geometric accuracy of road structure layers of ±1 centimeter.[13]

Digitization enables smart roads that improve lane capacity and allow for predictive maintenance

Like automation, digitization will also affect road design and construction in the near future. Until around five years ago, road design and construction rarely utilized any form of digitization and analytics, offering great potential for improvement.

First, roads will change from a purely mechanical asphalt structure with some systems for traffic density to a system of measuring and guiding. Using sensors either embedded in the road structure (in the case of newly constructed roads) or positioned around the road (in the case of existing roads) for guidance enables vehicles to drive closer together and is expected to increase lane capacity by 50 percent.[14] This approach is currently being tested by Chinese authorities and Cavnue, which is developing a connected and automated vehicle corridor between downtown Detroit and Ann Arbor in southeast Michigan.[15]

In addition, roads will be able to communicate surface conditions to AVs, e.g., friction levels due to cold temperature or water. Other types of sensors will be used for predictive maintenance, increasing the operational time of the asset while reducing costs and number of road closures. For example, the Dutch road agency already encourages construction companies to build in sensors in order to obtain data about the state of the road itself.

Another "smart" feature of roads will be electric charge-as-you-drive infrastructure. In 2018, Sweden was the first country to install an "electrified road" that charges electric vehicles.[16]

New construction materials increase road durability by 60 percent

Another trend that is going to disrupt road construction is the availability of new construction materials. Almost half of the costs of road construction stem from raw materials, particularly crushed rock, cement, oil derivatives (asphalt), water, and sand. Scientists have long searched for new materials to construct roads, particularly materials that are more durable and lighter.

Even though personal vehicles are expected to become lighter in the decades to come,[17] roads in 2050 will be required to be more durable than today due to increasing car ownership and greater lane capacity due to platooning.[18] Newly constructed roads can be built using new construction materials such as plastic in their asphalt mix, which make roads up to 60 percent stronger than conventional asphalt roadways and are thus suited to accommodate more vehicles per kilometer of road.

Existing roads will likely also have to undergo significant refurbishment to accommodate these requirements, which will call for significant infrastructure investment from EU governments. However, because the share of AVs and the associated stress on roads will rise gradually over a timeframe of 20 to 30 years, governments will have the opportunity to plan and coordinate these refurbishments in advance. Furthermore, these upgrades will be limited to the top-most layer (wearing and binding course) of roads and will thus be less cost-intensive than building new roads from scratch.

One example of a new construction material that improves road strength is one of humanity's most notorious waste products – plastic – which is not just lighter than asphalt, but can also be added in small pellets to increase the bulk of an asphalt mix. British entrepreneur Toby McCartney has developed a method for turning plastic bottles into small pellets and adding them to an asphalt mix, which results in roadways that last ten times longer than conventional roads.[19] Recently, a Dutch company even built a street made fully out of plastic to prove its resistance in a natural environment.

The state of Arizona has pioneered the use of rubberized asphalt, claiming that their solution may reduce cold weather and fatigue-related cracking to produce longer-life pavements. Other advantages include better rideability and less noise pollution.[20] Processing approximately 1,500 old tires per lane-kilometer, rubberized asphalt has the potential to significantly reduce waste streams. Another material was used by researchers at the University of Delft who developed an asphalt with small steel fibers which, with the help of a big magnet, can seal small cracks.[21] The civil engineering department at the University of British Columbia tested a similar technology in Thondebavi village (India).[22]

Road construction of the future: Speed will more than double, cost will shrink by 30 percent

Over time, road projects have gradually been getting longer (in kilometers), cheaper (per lane-kilometer), and faster (per lane-kilometer). The four megatrends we examined are set to disrupt road construction, making these undertakings significantly faster and cheaper by 2050. Based on current performance, if these megatrends moved the cost per lane-kilometer from the third to the second quartile, about 2 years and 7 months could be saved from the time the decision to build a median 88 lane-kilometer road is made until road completion.

Understanding drivers of speed and cost in road construction

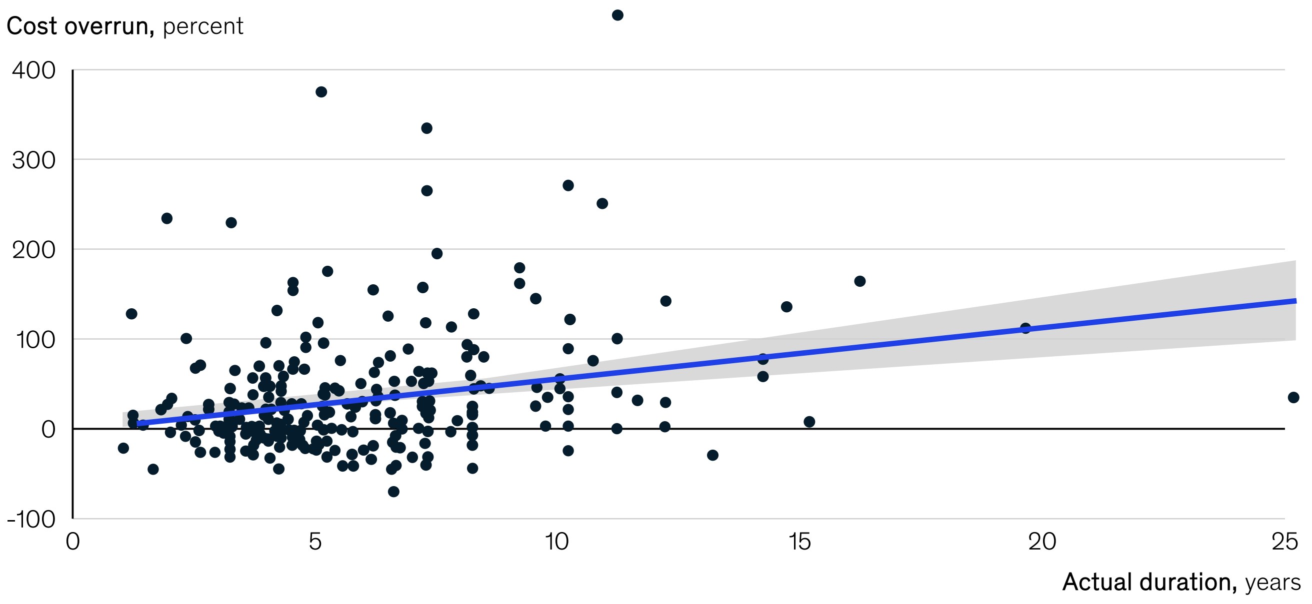
Speed is a key cost driver in road construction. Total construction costs depend to a significant extent on the time taken from the start of the pre-design phase to construction completion. Speed – or rather the lack of it – is also an important driver for cost overruns.[23]

There are workers to be hired, machines to be rented, and existing roads to be closed for the time of construction. Also, indirect macroeconomic costs from congestion correlate with the time needed for construction. Therefore, reducing construction time is key for many stakeholders, especially since road construction projects regularly overrun scheduled construction times (by up to 105 percent),[24] and hence budget (on average by 20 percent).[25] It is no surprise that longer projects often have high costs for each lane-kilometer that is delivered.

The longer a road project lasts, the greater the probability the project will exceed its budget (Exhibit 2). Longer projects are met with a double whammy of inconvenience, as their unit costs are also more expensive (Exhibit 3). Speed is crucial for protecting cost in both absolute and relative terms.

Exhibit 2

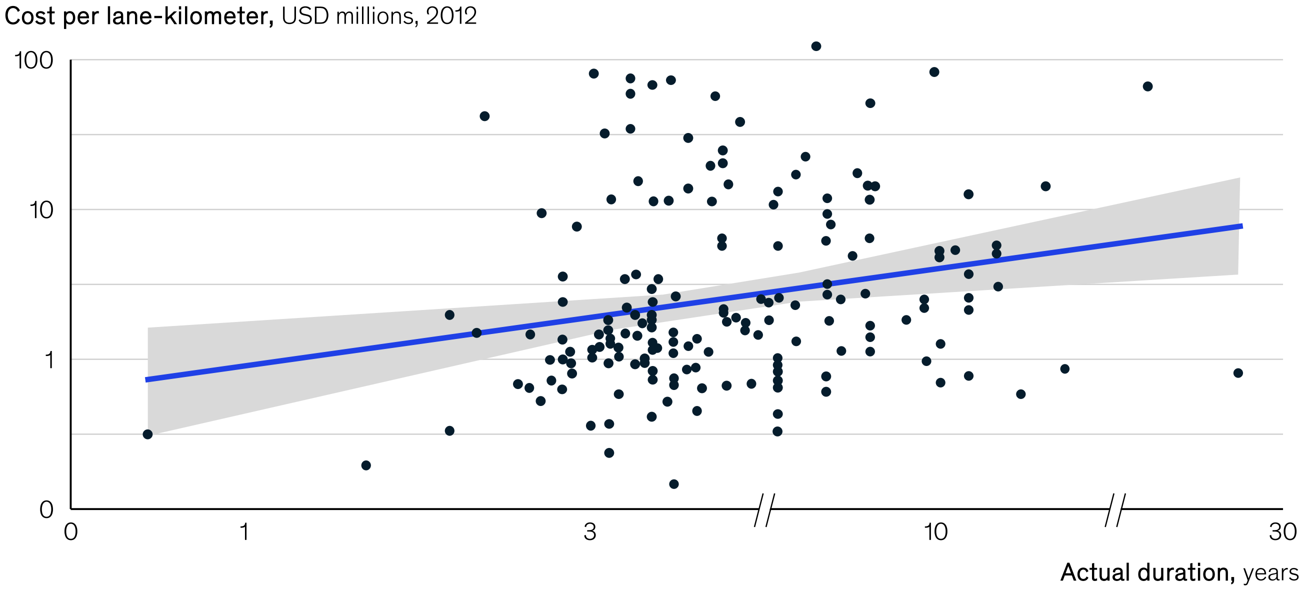
Cost overruns compared with project duration[1]



1. There is a statistically significant variation in cost overruns compared with project duration (p=0.00000127)
Source: Oxford Global Projects roads database

Exhibit 3

Unit costs compared with duration[1]



1. There is a statistically significant variation in cost per lane-kilometer compared with project duration ($p=0.00255$)
Source: Oxford Global Projects roads database

Future road construction is expected to lead to significantly shorter delivery times, reduced chances of cost overrun, and reduced unit costs. This is particularly significant for motorways, which have higher cost overruns than other types of roads.[26] Shortening project delivery also enables lower unit costs that arise with physically longer roads, while curtailing the downsides of projects that last longer.[27] The average duration from the final decision to build the road to its opening is 5.5 years.[28] Digital tools will improve each stage of a road project, supporting not only analysis of what road specification is required (and subsequently reducing waste from overproduction) but also both faster design and faster construction through standardization.

Since 2000, the median average cost per lane-kilometer has declined from USD 9.5 million to USD 7.6 million.[29] This figure includes all project-related costs such as land and property, which are not part of the scope of this analysis. To gauge the disrupting effect of megatrends on road construction costs, we focus on the lifetime cost[30] of a road, which is mainly driven by direct construction cost that, in turn, can be split into cost of material and cost of installation.

Over the 25-year lifespan of a road, the cost per lane-kilometer amounts to USD 2.0 million,[31] of which direct construction costs account for approximately 85 to 90 percent. If the introduced improvement levers get rigorously implemented, the share of direct construction cost per lane-kilometer is expected to remain largely unchanged, since the three main cost drivers – materials, earthworks, and installation – bear significant optimization potential.[32]

— **Materials.** While the materials for the roadbed will not change dramatically, new materials like plastics will be used for the upper layer of the pavement, driving down its cost. Due to the increased road strength achieved through new materials, the pavement will also be thinner and consume less material.

- **Earthworks.** Even though they are comparatively simple from a technical perspective, earthworks have a substantial cost impact and are prone to delays due to necessary reworks. A variety of smart machine guidance technologies that aim at reducing the time and cost of earthworks is currently being trialed, among them GPS-based excavation instead of laser-guided excavation, 3-D grade control, tilt rotator control, and remote monitoring. Through such approaches, operators achieve higher degrees of standardization and discover discrepancies as they occur.

- **Installation.** Machine-driven installation will be faster due to a higher degree of automation and use of digital tools, thus reducing the time machines need to be rented and personnel needs to be hired. Additionally, a higher degree of automation will also reduce human error in road construction. Given that there is on average approximately 2 to 3 percent of rework to be done in each project, this will further drive down lifetime cost.

Another reason why cost is expected to decrease is that less road maintenance, which represents about 10 to 15 percent of lifetime cost, will be required. This share will stay constant, since saving potentials in materials and installation are almost at the same level. New materials such as plastics typically extend the lifespan of a road by 100 to 300 percent. This holds true even without applying predictive maintenance, which will have an additional life-prolonging effect. Thus, the total lifespan of roads will likely not only be extended from an average of 12 years today to 25 to 30 years in the future, but also incur significantly fewer maintenance costs than today. As a result, assuming constant land and property cost, the average cost per lane-kilometer is expected to fall by around 30 percent to USD 1.6 million.

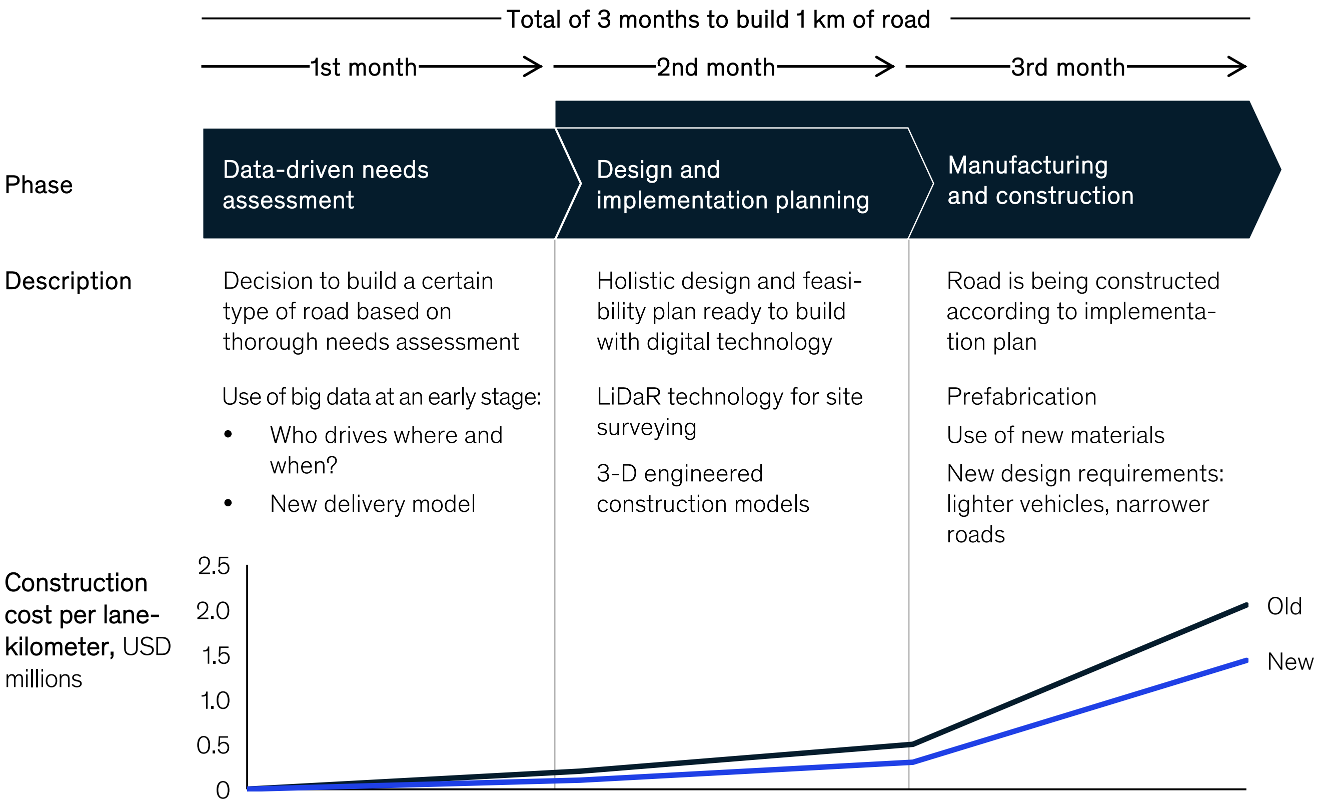
An improved process flow for road construction significantly decreases construction time and cost

By reducing the time and cost of multiple construction process steps and making other steps obsolete, the four megatrends can be expected to completely disrupt the traditional road construction process. The new process is likely to consist of three key steps: 1) data-driven needs assessment, 2) design and implementation planning, and 3) manufacturing and construction.

Together, these steps build a distinctive process through which the direct construction cost per lane-kilometer is expected to decrease by roughly 30 percent by 2050 compared to today (Exhibit 4).[33] This reduction in cost is evident at each stage of the project and does not require a more costly initial outlay for the project.

Exhibit 4

The new process flow for road construction will decrease construction time and cost by up to 30%



Source: Expert interviews

In the following, we are going to examine the three overarching steps of the future road construction process in detail and describe how they differ from current processes.

Step 1: Data-driven needs assessment

Future road construction is expected to use advanced analytics to create data-driven needs assessments. Car manufacturers and navigation apps already collect billions of data points to understand how many people are traveling from point A to point B and what time of day and year. Capacity and other road parameters can also be specified. If fully anonymized, government authorities could leverage this real-time data in what-if analyses and simulations to plan and prioritize road projects accordingly, rather than rely on lengthy traditional needs assessments, such as traffic counting. The same data could be used to develop better traffic management plans to ease the impact of construction closures.

Advanced analytics can offer evidence-based guidance on whether and, if yes, to what extent a certain road project can actually help improve traffic flows. Increasing reliance on data-driven approaches could also help speed up the political discussion around approval processes. Currently, the approval process often slows down road construction from the very beginning, but advanced analytics could substantiate or refute claims with a convincing and transparent fact base. Industry experts estimate that coming to a final decision and deriving road parameters in many cases could be accomplished within a month's time.

Step 2: Design and implementation planning
Once a final decision to build a certain type of road is made, the implementation planning phase is launched. This phase includes all activities from feasibility study to construction plan. New technologies recently trialed in construction promise to increase the efficiency of this phase dramatically.

Conventional road construction companies split this preparatory work into three phases in which 1) the road is surveyed ("What are the current conditions and where are the deficits?"); 2) a high-level work plan is drafted ("What do I want to build and when?"); and 3) the work plan is substantiated by the individual contractors ("What equipment, material, and staffing levels do I need, when do I need them, and where do I implement the work plan?"). All in all, this often takes 6 to 12 months. However, the same outcome could be generated in just 2 months if the right technologies were consistently used. Among the numerous technologies recently introduced in the construction space, two are particularly helpful in such planning phases:

— **LiDAR.** Light detection and ranging methods have become increasingly popular, as they allow users to make digital 3-D representations of objects and even landscapes, and can also be mounted on cars. If applied to drones, lidar could revolutionize labor-intense and time-consuming site surveying steps, which currently involve manual inspections of the proposed construction area. Such lidar methods could speed up the preparatory phase of road construction.

— **5-D-building information modeling.** Construction time of infrastructure projects and other megaprojects can also be reduced through the use of 5-D-building information modeling. These models enable construction players to virtually build a certain project twice – once digitally, and once on site. Digital twins can help uncover potential challenges and other unforeseen difficulties during implementation and validate the substantiated implementation plan. Through simulation, this further reduces the risks inherent in construction, likely improving speed.

This phase also includes coordination with utility providers that varies in length and nature depending on the type of road that is going to be constructed. While such consultations often derail the overall construction process today, innovations in road construction can help to speed it up. Data-driven analyses allow utility providers to immediately understand whether they need to be part of the process at all, and if so, which pipes and cables will be needed. On top of that, new materials used in road construction change the way cables are installed. Prefabricated plastic roads typically provide a duct, which significantly simplifies the interaction between construction companies and utility providers.

Step 3: Manufacturing and construction
Automation and the availability of new construction materials will completely transform the lengthiest process step, namely the construction itself. Road construction usually involves a significant proportion of manual tasks requiring crew sizes of 20 workers on average. However, repetitive manual tasks, such as distributing the material of each layer, could be automated by vehicles that recognize barriers and the depth of material needed at each level, similar to farming.[34] Until recently, ensuring that construction material is continuously added to the machine had been a major challenge. However, promising innovations involving multiple AVs have since been trialed successfully, enabling construction workers to substantially reduce the time required for laying the road's foundation.

Automated solutions also have two other distinctive advantages worth considering. First, machines guided by such solutions do not need breaks and time off. Shift workers can continuously supervise the progress the machines make. Second, machines are unrivaled when it comes to precision, which is particularly important, as rework often causes delays. The manufacturing sector is also famously good at continuous improvement, with average value added per hour increasing at four times the rate of construction since 1995.[35]

While automation will shorten the time necessary for building the bottom layers, the availability of new construction materials will significantly alter how the upper pavement layer is installed. Unlike in other areas of construction, such as residential buildings, where some parts are already prefabricated, most road elements are still cast on site. Roads featuring plastic, however, will allow for modularization and prefabrication, and companies that can begin producing the surface in advance and offsite are able to start and finish much earlier than their competitors. The Dutch company KWS, which has developed a prefabricated, modular roadway made from recycled plastic, even claims that its “PlasticRoad” can be constructed up to 70 percent faster than traditional roadways.[36] If it were possible to standardize at scale the most difficult-to-build parts such as drainage systems, total construction time would decrease even further. In addition, future road design featuring lanes that are up to one-third narrower will also contribute to a reduction in construction time.[37]

The road construction industry needs to prepare for increasing competition

The four megatrends of autonomous driving, automated production, digitization, and advances in road construction materials as well as new process flows are bound to make road construction much faster and cheaper. Unlocking such substantial value from road construction is sure to attract new players.

Emergence of new value pools and market entrants will shake up the industry

Whether conventional construction companies – with their reliance on manual labor and low levels of automation – will be able to develop the technological capabilities necessary to build these tech-heavy roads themselves remains an open question. If conventional construction companies fall behind, high-tech players developing AVs – such as Alphabet, Apple, and Tesla – will be incentivized to form partnerships with each other or with startups in the smart road construction business.

Although these companies are unlikely to enter the road construction business as end-to-end players, they have made some first forays into the road systems. Alphabet subsidiary Sidewalk Labs is planning to build the world's first "smart neighborhood" in Toronto, which includes smart streets[38], while Tesla offshoot The Boring Company is pitching "smart tunnels" as a solution to gridlock in American cities.

If traditional construction companies fail to develop the expertise to adopt these innovations in road construction, they run the risk of becoming raw material suppliers to more tech-savvy players, who could capture newly emerging value pools through new business models, e.g., dynamic tolls based on road congestion. Overall, the emergence of new technologies and business models in the road construction business will likely increase competition, which could cause the overall cost of road construction to plummet further.

The four megatrends are bound to disrupt road design and construction over the next 30 years, making it not only faster and cheaper to build roads, but also unlocking significant economic and societal value through better roads. Two examples of this: 1) The European Commission estimates that traffic congestion costs as much as 1 percent of GDP per year – corresponding to a staggering EUR 100 billion p.a.[39] 2) Smarter traffic management has the potential to curb CO_2 emissions of cars by up to 30 percent.[40]

A call to action

The opportunity is clear in the race for the road of the future, but Europe is at risk of falling behind. With new industrial heavyweights, such as China, not pinned down by large legacy road systems or fragmented regulation, players in the European road ecosystem have more hurdles to leap. These players, especially governments and construction companies, need to take action to stay competitive in the race towards the next transport revolution.
A coordinated action plan may comprise five approaches:

Establishing standards for "smart roads"
As technological innovations in road design emerge, companies in the US and China have already begun trialing new approaches, often with state support. However, there are still no established standards for the road of the future, which will be narrower, smarter, and more durable.

European governments could thus seize the initiative and establish a broad alliance of relevant players from the European private sector (especially construction companies and car manufacturers) to start defining draft standards for smart roads in the EU that help channel innovation without being overly burdensome. In this context, European governments could bundle their efforts within already existing organizations like the Conference of European Directors of Roads, consisting of representatives from 27 European countries' national road authorities, which has already set forth road digitization as a strategic priority.

Jump-starting innovation through public procurement
To support the development of the necessary technologies and standards, EU governments should strategically leverage public procurement. Models of this include providing dedicated funding for pilot projects or giving preference to players that participate in the standard-setting process. As an example, the UK government has launched an initiative through Highways England to offer a total of GBP 20 million to companies that provide "creative solutions" for the construction of "digital roads."[41] This illustrates one approach by which European governments could jump-start innovation by offering targeted financial incentives.

What is more, in 2019, the Walloon Complementary Infrastructure Financing Company (SOFICO) enacted the Lighting Plan 4.0, which will be executed in a public–private partnership. The partners committed themselves to installing novel lighting infrastructure on main roads and motorways in the Walloon region. These lighting points (about 100,000 in the first four years) will be equipped with several sensors to manage light intensity according to traffic density. To anticipate all possible usage scenarios, in particular future self-driving vehicles, the consortium will also install roadside units that include presence sensors, doppler radars, and Bluetooth cameras, which will be managed remotely. The objective is to transform Walloon highways into Europe's first connected highways.[42]

Establishing cooperation and collaboration for capturing the new value pools
Similarly, as road designs start adopting "smart technologies," cooperation and collaboration between European construction companies and nontraditional players, such as sensor manufacturers, data analysis and artificial intelligence experts, or car manufacturers, will become central to capturing these new value pools. Governments could play a pivotal role here by linking domestic road construction companies to research institutions in order to secure valuable first-mover advantages.

Leveraging new financing models
Roads designed to meet the outlined criteria (e.g., autonomous driving) allow road operators to implement novel financing models like smart tolls or monetization of car data through which the large amount of capital needed to upgrade existing road infrastructure could be mobilized.

Building required new skills and capabilities
In the next 20 to 30 years, road construction will change from a still rather traditional and analog business that largely relies on manual labor to a highly automated digital enterprise. Public works agencies could build the relevant capabilities and skills needed to develop appropriate standards, embedding innovation-supporting mechanisms in public procurement and leveraging new financing models. By contrast, construction companies need to build the relevant capabilities and skills required for deploying automated machines and digital tools (such as lidar-equipped drones) to fully realize the cost-saving and quality-improving potential these technologies hold.

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By 2050, the road of the future will be found in countries such as China, the US, and others. Until then, whether or not Europe will take the road less traveled will make all the difference.

End notes

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[24] Anastasopoulos et al., 2012; Empirical Assessment of the Likelihood and Duration of Highway Project Time Delays (Journal of Construction Engineering and Management)
[25] Ansar et al., 2014, p.54
[26] Oxford Global Projects road database. There is a statistically significant variation in cost overruns for motorways compared with non-motorways (p=0.036)
[27] Ibid. There is a statistically significant variation in unit cost compared with road length (p=0.000858).
[28] Ibid.
[29] Oxford Global Projects roads database. The earliest road project opened in 1954.
[30] We treat total cost of ownership as a function of material and installation cost as well as maintenance. Land and property prices will therefore need to be added to get to total project cost.
[31] Estimation based on expert interview. The cost of road construction varies widely by a broad range of factors, including labor costs, geographical factors like soil, terrain, and climate (which affect the type and proportion of materials needed), the availability of materials, and fuel costs, among others.
[32] The range is based on expert interviews and the Oxford Global projects roads database of 1,508 projects.
[33] The cost per lane-kilometer includes the whole project cost divided by the number of lane-kilometers there are on the project. This whole project cost includes the advance works, archaeology, land and property, planning and design, and the residual network, in addition to direct construction costs.
[34] Expert interviews
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