McKinsey&Company

Gearing up for growth
Future perspectives on the global truck market

Advanced Industries May 2016

Contents

Introduction

In the years since the Great Recession, the global truck industry has seen two major developments: profit pools have globally recovered from the crisis while at the same time the sizeable profit pools that once characterized the Western European markets have begun to spill over into the US and emerging markets. Also, as the key findings of and insights from our McKinsey Truck Initiative indicate, further growth and more rebalancing of the profit pools are very likely to come over the next four to five years – for 2020, the Truck Initiative predicts a global profit of EUR 11.8 billion, i.e., 40 percent growth over 2008.

In light of these imminent shifts and the resulting challenges ahead, this study aims at providing a fresh perspective on the future of the global truck market through 2020. With empirical support from new market research conducted in 2015, McKinsey both identified potentially game-changing market trends and highlights the most relevant topics for the truck industry in the years to come.

Following a detailed overview of the ten trends shaping the future of the global truck market until 2020, the chapters in the main part of this publication present "Deep dives on key industry topics" and provide answers primarily to the first of the following two overarching questions looming large in the industry: What are the biggest changes, chances, and challenges ahead, and how can the resulting potentials be captured?[1]

The first chapter here, "The Chinese truck market," focuses on the challenges of price pressure, e.g., due to overcapacity and the expansion of emerging Chinese market players, while the next chapter, "Modular strategy," elaborates on the many advantages of the use of common components across different platforms and brands. The last three chapters give an overview of and explore "New service and business models" – with a special focus on "Opportunities through telematics" and an outlook on the promises and risks of "Autonomous driving."

This publication is intended to offer readers insights into crucial topics in tomorrow's global truck market. Instead of providing extended text descriptions, the articles collected here focus on highlighting key facts and developments. We very much hope you will find our findings interesting and inspiring and we would be delighted to further discuss them with you.

1 Answers to the second question will be provided for the most part in a forthcoming expanded and updated version of this report.

Key insights from the McKinsey truck initiative

Our McKinsey Truck Initiative resulted in several insights with regard not only to the industry's profit pools and their shifts but also to its core changes as well as trends and opportunities:

Profit pools and shifts

- **Industry rebound.** In 2013, the global truck industry collectively earned a profit pool of EUR 6.2 billion (~ 4.2 percent margin), just 26 percent short of the 2008 level.
- **Profit and margin gains.** The industry has the potential to reach a norm year profit of EUR 11.8 billion (~ 5.8 percent margin) by 2020.
- **Geographic shifts.** The industry recovered sharply after the 2009 crisis; however, profits are shifting from Western Europe to the US and emerging markets/Rest of World. In the long term, Western Europe will account for ~ 20 percent of global profits – compared to a precrisis share of ~ 55 percent.
- **Regionalization shifts.** Global players will gain in importance, increasing their profit pool share from 38 percent in 2008 to 42 percent in 2020.

Core changes

- **EE profit erosion.** Main growth drivers of sales revenue are Eastern Europe, emerging markets, and the US; however, absolute profits in emerging markets will remain low due to increased competition from strengthened local players as well as localized international OEMs.
- **Market barriers.** Technological advantages of Western OEMs and emissions regulation will prevent emerging market players from entering Western markets in the short and medium term.
- **Mid-market opportunity.** Attractive profit pool segments in China and India are the technologically advancing mid-market segments. Participation in the "run to the middle" is thus a prerequisite to secure an option for participating in the increasing mid-market profits in the longer term.

Trends and opportunities

- **Shift towards services.** Triad markets will see a continued shift towards services and alternative business models (e.g., pay per kilometer).
- **Reg-driven investment.** The convergence towards tighter emissions norms implies investments and a cost of around an additional EUR 100 million for the industry (net of pass-throughs), especially in emerging markets.
- **Greater fuel efficiency.** After the emissions regulation of the past decade (EURO 6, EPA10, JP09), investments into CO_2 reduction measures will increase due to both upcoming regulatory frameworks and continued competitive pressure on TCO reduction (e.g., increased fuel efficiency) in the freight-forwarding industry.
- **Profit from scale.** Major industry players continue to strive for unlocking the additional profit potential of EUR 1.4 billion by realizing global scale effects stemming from, e.g., modularization and global engine and component strategies.

Overview of 10 trends shaping the global truck market until 2020

Key trends shaping the truck market

Until 2020, the global truck industry will be shaped by 10 key trends in 4 categories

Market economics

1 Structural shifts
Rising sales due to economic development

2 Raw material volatility
Volatile raw material markets with overall falling prices

3 Labor cost changes
Rising labor cost, especially in emerging markets

Industry regulation

4 Emissions standards
Stricter regulation of NO_x and particulates, especially in emerging markets

5 Fuel efficiency
Increased requirements on fuel efficiency (CO_2), both regulatory driven and TCO driven

Industry dynamics

6 Increasing competition
Price pressure through increasing competition

7 Rising standards
Shift to higher-value trucks, and increased aftermarket services in emerging markets

OEM levers

8 Modular strategy
Use of common components across different platforms and brands

9 Service and business models
New service and business models, e.g., pay per kilometer

10 Footprint/ LCC
Shift of production footprint towards low-cost countries

Ten trends shaping the industry through 2020

In the course of the Truck Initiative[1], McKinsey identified ten market trends that will change the economic and political context in which truck manufacturers operate. For overview purposes, these trends can be grouped into four categories: market economics, industry regulation, industry dynamics, and OEM levers.

The first three categories are comprised of global developments that are largely outside the control of truck manufacturers. However, individual manufacturers can take steps to craft an effective response to some of them. By contrast, the fourth category comprises actions that OEMs can take to extend their business models, innovate their product strategies and footprints, and create cost-saving efficiencies.

Market economics

Market economics. The markets for medium- and heavy-duty trucks tend to expand in step with freight volume, which rises and falls in line with the gross domestic product. Global GDP will grow at over 5 percent annually from 2012 until 2017, leading to an increase in freight volume and, thus, growth in the truck markets. On the other hand, labor cost is steadily increasing, especially in emerging markets. Consensus data, for example, project that labor cost will almost double in China from 2013 to 2019. And, while prices for materials are generally falling and are likely to continue doing so, raw material price volatility is increasing significantly and will further complicate sourcing strategies.

Industry regulation

Industry regulation. Another external force acting on the truck industry is regulation. As traditional heavy truck exhaust emissions like nitrogen oxides (NO_x) and particulate matter (PM) trend toward zero in the Triad countries, emerging markets are catching up fast, which will add to truck maker cost pressures in these low-cost-focused markets. However, because most key emerging economies are adopting EU emissions standards, global truck OEMs can standardize technologies across markets to gain increased scale economies and, thus, advantages over smaller players.

At the next level of emissions regulation, governments are beginning to regulate CO_2 emissions via increasing fuel efficiency requirements. In fact, Japan and the US have already defined regulatory schemes that will become effective starting with model years 2015 and 2017, respectively. The EU and China expect to implement CO_2 regulation during the 2015 to 2020 time frame. No concrete plans exist for Brazil, Russia, or India at the moment. Since CO_2 emissions are directly linked to fuel consumption, customers will save on fuel costs as trucks become “cleaner” with respect to CO_2 emissions.

In 2002, fuel made up 30 percent of the total cost of ownership (TCO) for a 40-ton long-haul tractor in Germany, for example. By 2011, it had risen to 37 percent – an absolute increase of over 43 percent – due to diesel price hikes, while most other costs remained relatively constant. Given this increased fuel cost burden, truck owners are well prepared to pay for advanced fuel-saving technologies as long as they are convinced of a sufficiently short pay-back period. This is a significant revenue and profit opportunity for truck OEMs that add fuel-saving technologies to their vehicles (see text box).

1 In December 2014, McKinsey conducted interviews with truck industry experts in the key markets Western Europe, US, Japan, Eastern Europe, Turkey, Brazil, Russia, India, China, and Rest of World. The goal of these interviews was to better understand which trends will shape the global truck industry.

Fuel-saving technologies

Truck OEMs have a rich bundle of fuel-saving technologies at their disposal that can theoretically capture cumulative savings of 50 to 65 percent. Solutions include near- and longer-term diesel improvements, vehicle upgrades such as advanced aerodynamics and active driver influence technologies, hybrid-electric vehicle (HEV) powertrains, and the shift to natural gas from diesel fuel.

However, not all viable new fuel economy technologies provide the same levels of profitability from the OEM's perspective. Viewed in terms of TCO, for example, HEV solutions for a typical medium-duty truck could result in negative OEM unit margins (~ -10 percent) due to the costs associated with hybrid batteries. In fact, McKinsey analysis reveals major differences in profitability across solutions, with HEVs showing the worst bottom-line performance. To become profitable, OEMs need to cut hybrid costs by 60 to 80 percent. While hybrid technologies are the worst in terms of profitability, both compressed and liquefied natural gas (CNG/LNG) offer very good economics, followed by active driver influence technologies. McKinsey also found that most diesel engine and transmission improvements still provide viable opportunities. The attractiveness of some solutions will vary by region or depend on the gross vehicle weight and usage pattern.

Industry dynamics

Industry dynamics. Competition among truck manufacturers will likely increase through 2020. On the one hand, emerging markets still exhibit significant overcapacities, leading to a strong and increasing price competition. China, for example, was only using about half of its installed manufacturing capacity in 2013. On the other hand, emerging market – and especially Chinese – truck manufacturers are increasingly finding a customer base in Eastern Europe and Latin America (see text box).

Trucks beyond borders: Chinese truck manufacturers successfully expand into South America and Eastern Europe

Chinese truck manufacturer JAC offers a prime example of what is possible when OEMs expand into new markets. JAC became active in South America in 2009. The company sold an initial 381 units that first year and reached 2,178 units in 2014, increasing its market share in the region from 0.2 to 1.1 percent. Foton entered South America one year after JAC and experienced similar gains. The manufacturer sold 250 units in 2010 and 2,405 units just four years later, growing its market share in the region from 0.1 to 1.2 percent.

Eastern Europe is also a target for truck manufacturers – particularly those in China – looking to expand beyond their borders. Weichai entered the Eastern European market in 2007. In its inaugural year in the region, the manufacturer sold 715 units of its Shaanxi Heavy brand. By 2012, the number of units sold had grown ten times, and Weichai had increased its market share in Eastern Europe to 3.9 percent.

Along with growing competition, increasing customers' demand for quality, features, and service in emerging markets also plays a role in intensifying industry dynamics. For example, customers want more powerful trucks with greater carrying capacity to handle the habitual overloading vehicles face and more robust suspension systems to navigate poor road conditions. They seek good reliability to keep utilization levels high and to cope with the practice of overloading without sustaining serious damage. Quality aftersales service represents another critical need. Fleets want high levels of parts availability, extensive service networks, and timely service. In addition, customers with large fleets that cross borders seek international customer support, cross-border financing, strong fleet management capabilities, telematics systems, and mobility packages. Together, these demands are driving the shift from low-cost toward higher-value, heavier trucks and more aftermarket sales, especially in the Chinese market.

OEM levers

OEM levers. Heavy-truck players are not just subject to the external market forces of economics, competition, and regulation. They also have several levers at their disposal to increase their profit pools. Their ability to develop new business models could generate significant revenue streams, while the continued shift of production to low-cost countries can yield massive savings. Companies are already pursuing some of these options. For instance, some OEMs are actively growing their aftersales and service income: one European player increased the aftersales and service portion of its revenues from 20 to 26 percent from 2004 to 2012. In doing so, it discovered that aftermarket services could boost its margins by up to 1.5 percentage points, helping the company smooth out the big ups and downs of its cyclical performance.

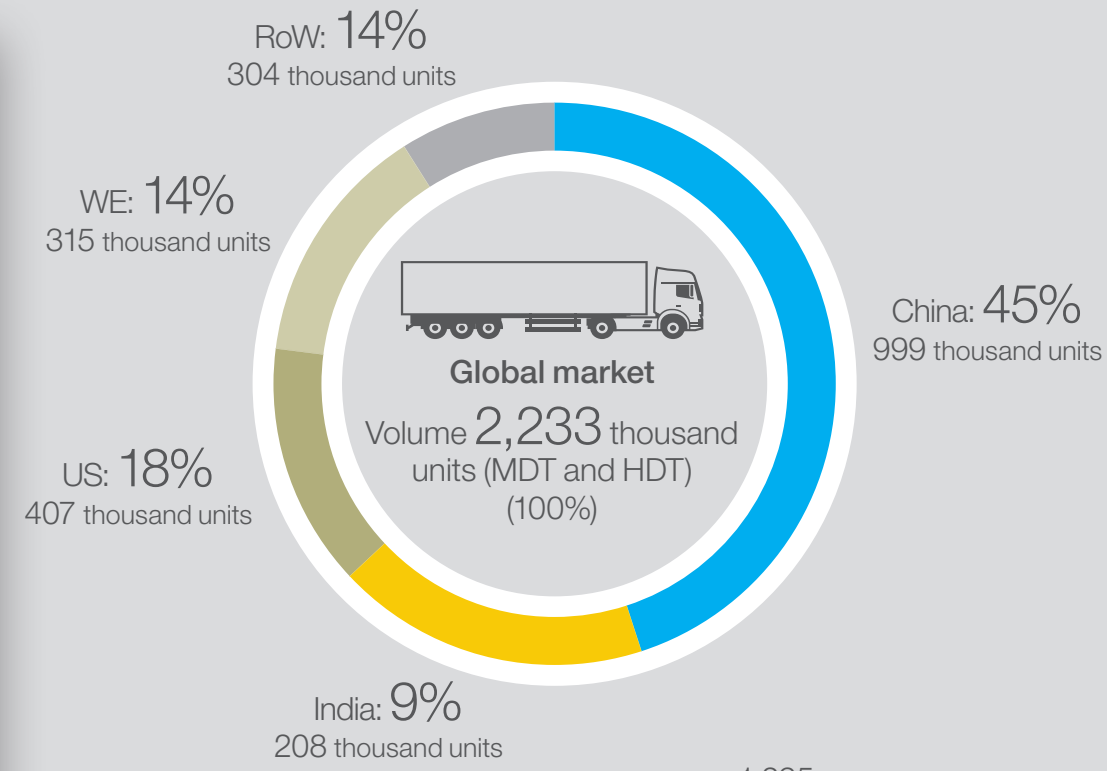
The development of modular components for use across different platforms can also lead to significant savings through cost efficiencies. Daimler, for example, introduced a common engine platform for heavy-duty applications and claims that this particular modular strategy has helped decrease costs by 6 to 10 percent even after production volume doubled. Looking ahead, Volkswagen has announced plans to introduce a modular toolkit for its heavy trucks next year.

Deep dives on key industry topics

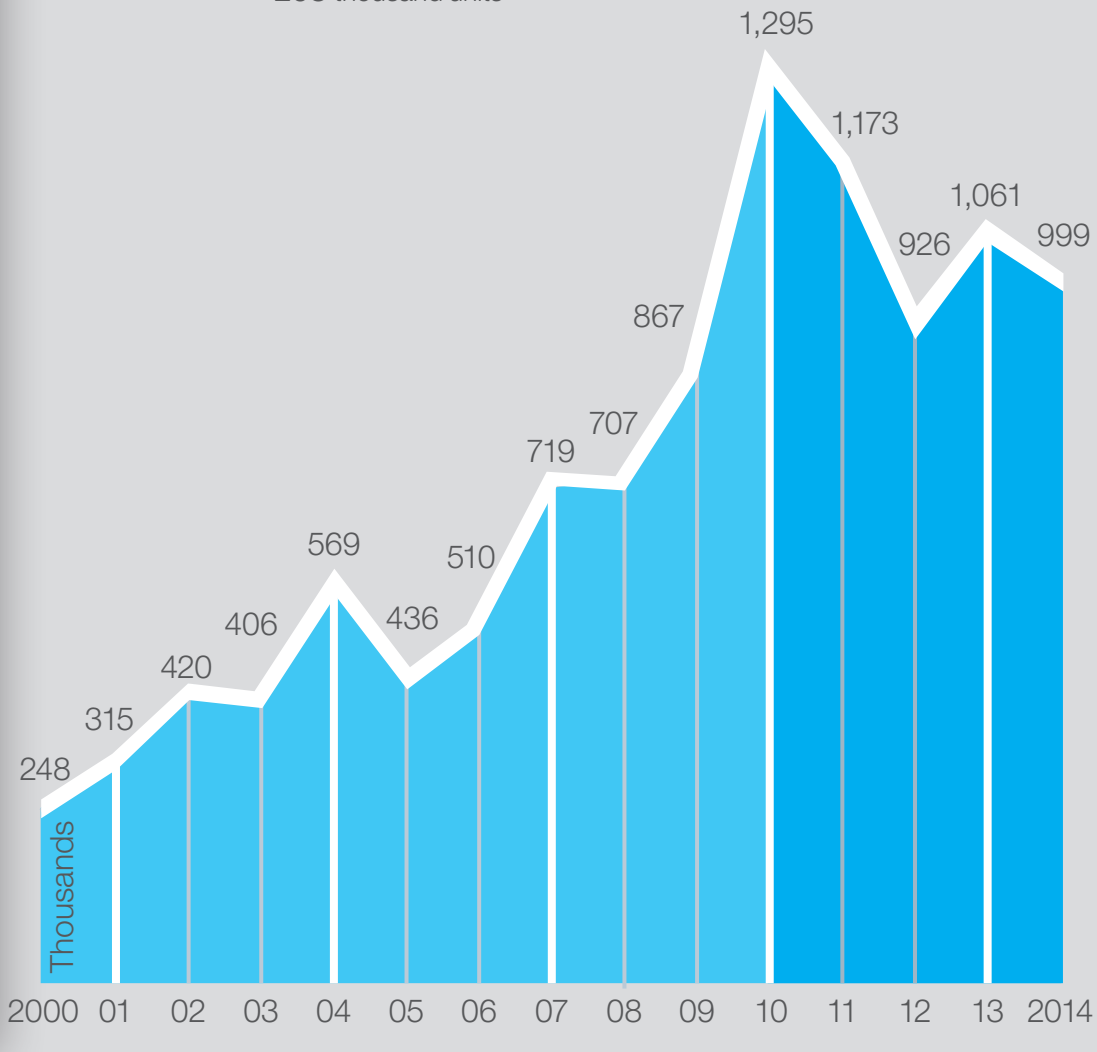
I. The Chinese truck market

Volume development in the Chinese truck market

China is the largest national truck market worldwide in terms of volume figures as of 2014



Period of rapid volume expansion followed by sharp decline



Although the Chinese market for medium- and heavy-duty trucks experienced a sharp decline in recent years, it remains the world's largest national truck market by volume. It began expanding rapidly in 2000 and continued to do so for the next decade. A sudden loss of volume after 2010 is just one of the developments to shake up the market: fast-moving changes are also evident in the sophistication of transport infrastructure, OEM and customer structures, and truck price-performance ratios. A look back at the market's recent history reveals the extent to which change has been the norm.

A look in the rear-view mirror

1997 - 2005: start of domestic production

- Several new local brands established (e.g., Foton, Hualing)
- Volume shift from medium- to heavy-duty trucks begins
- Rapid expansion of road network

2005 - 2010: fast market expansion, step-change in logistics system

- Volume grows quickly
- Local OEMs upgrade products, partly by sourcing components internationally
- Multiple new brands compete for market share, resulting in price pressure (real price development is flat)
- Dealer and service networks expand

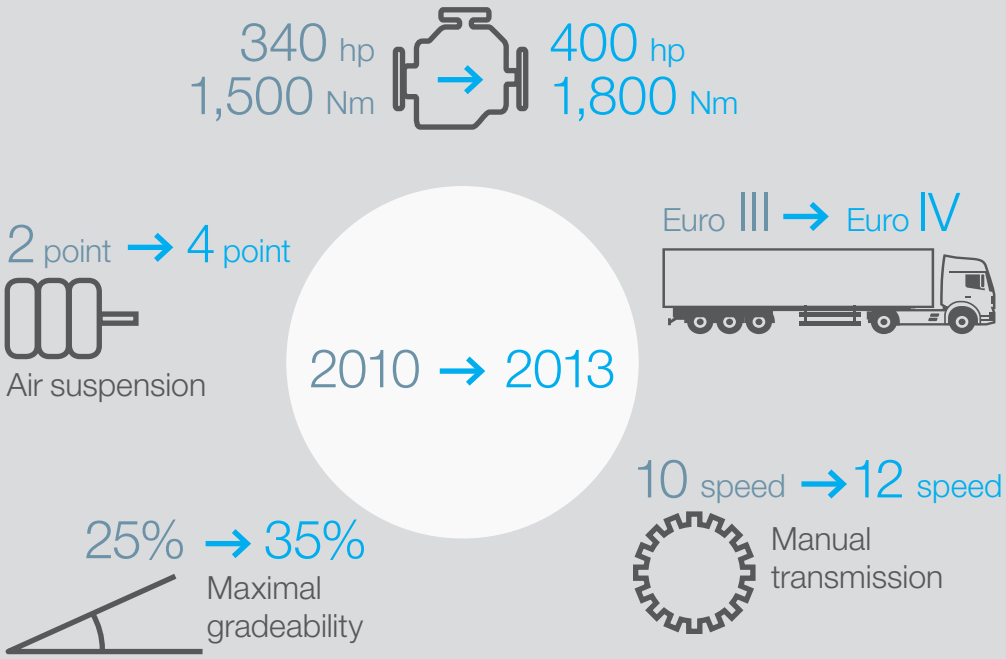
2010 - 2011: rapid decline in truck volume

- Underlying economic growth slows, leading to underutilization of the rolling fleet built up over the previous expansion period
- As a result, sales of new trucks decline sharply

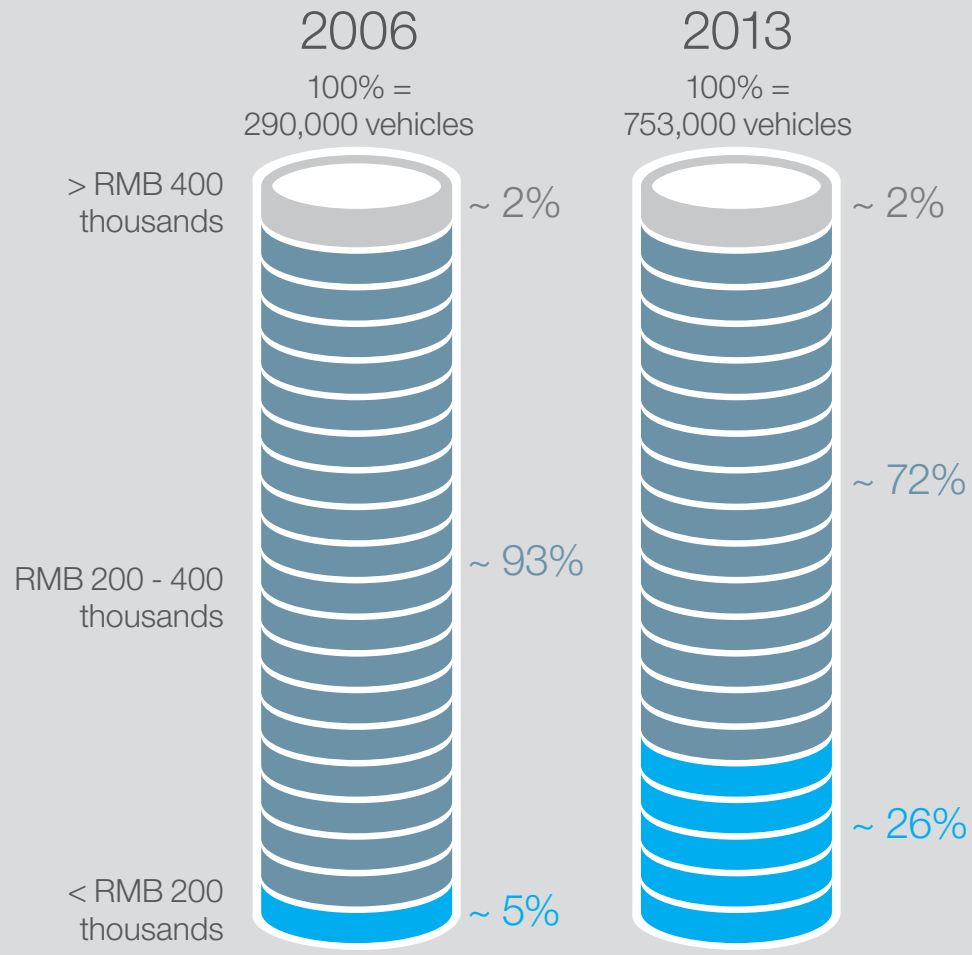
While the market is stabilizing, current volume demand is still significantly below OEM production capacity. The transport company landscape also remains very fragmented, and short-term cash flow is a very important consideration for these companies when deciding which trucks to source. The market for premium trucks (served mostly by imported vehicles from European OEMs) remains a niche market accounting for a very small share of total truck volume.

Performance and price development of Chinese trucks

Chinese truck makers have noticeably improved their product offer over the last 5 - 10 years – example of a Chinese top-model truck



The bulk of truck sales occured in price segments below the RMB 400,00 level[1]



1 2006 real price level, inflation adjusted for 2013

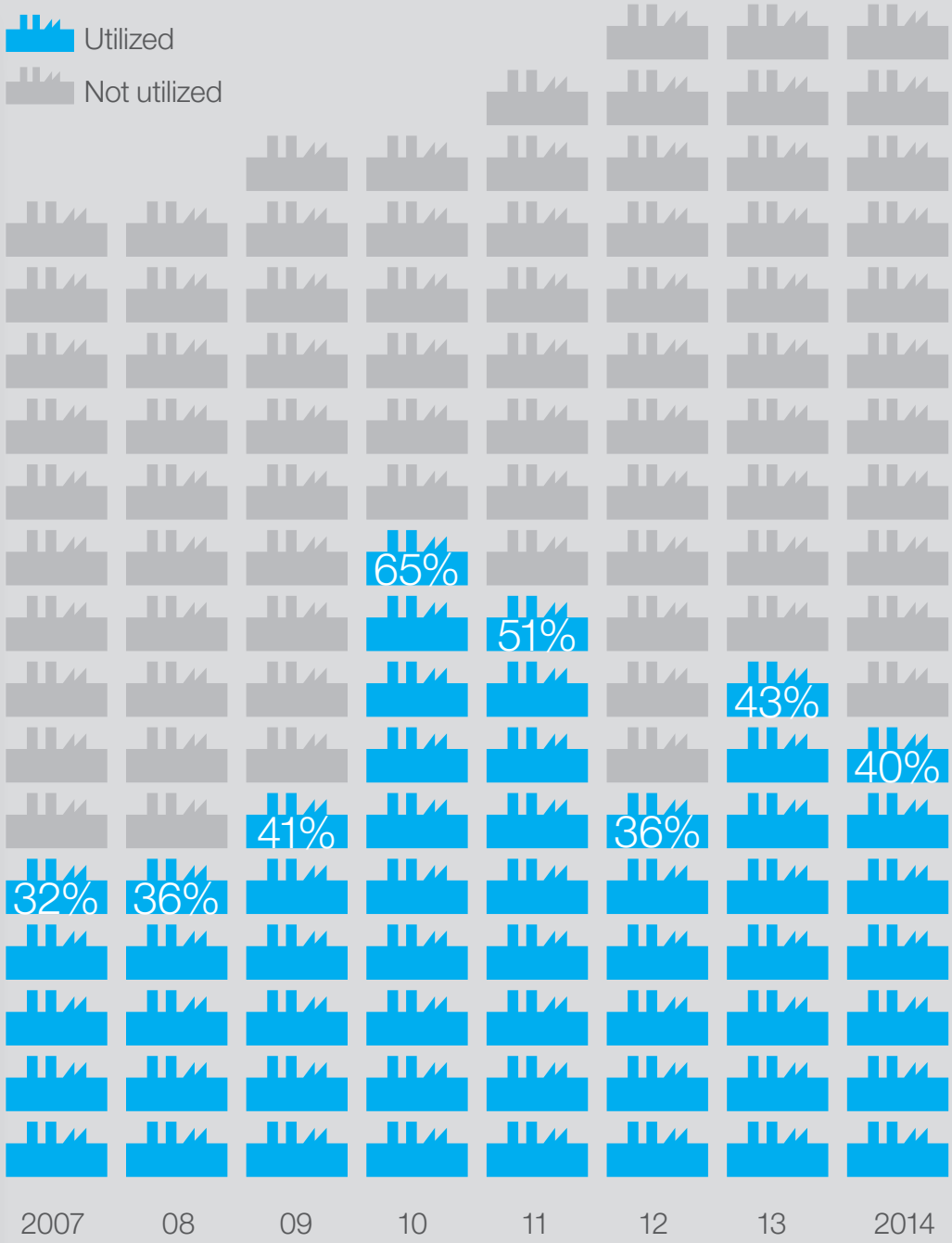
In recent years, Chinese truck makers have dramatically improved their products – and their customers have reaped most of the benefits.

Improved truck specifications represent the largest product-related leap, which has taken place across essentially all component groups (engine, gearbox, chassis, cabin). While higher specifications do not automatically translate into better performance, customers are also starting to notice a step change in the quality and daily operational performance of Chinese trucks. Several applications that previously required imported Western trucks can now be sufficiently served with locally built models.

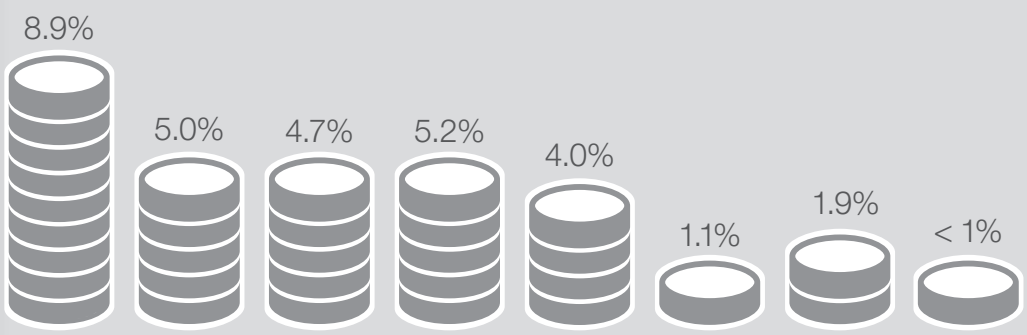
During the same period, the development of the real price for trucks in the Chinese market has been relatively flat – inflation adjusted, prices have even gone down, as the graph shows.

Local production overcapacity and the profitability challenge

Truck manufacturers factories have been significantly underutilized for a number of years



Overall, profitability has declined since 2007

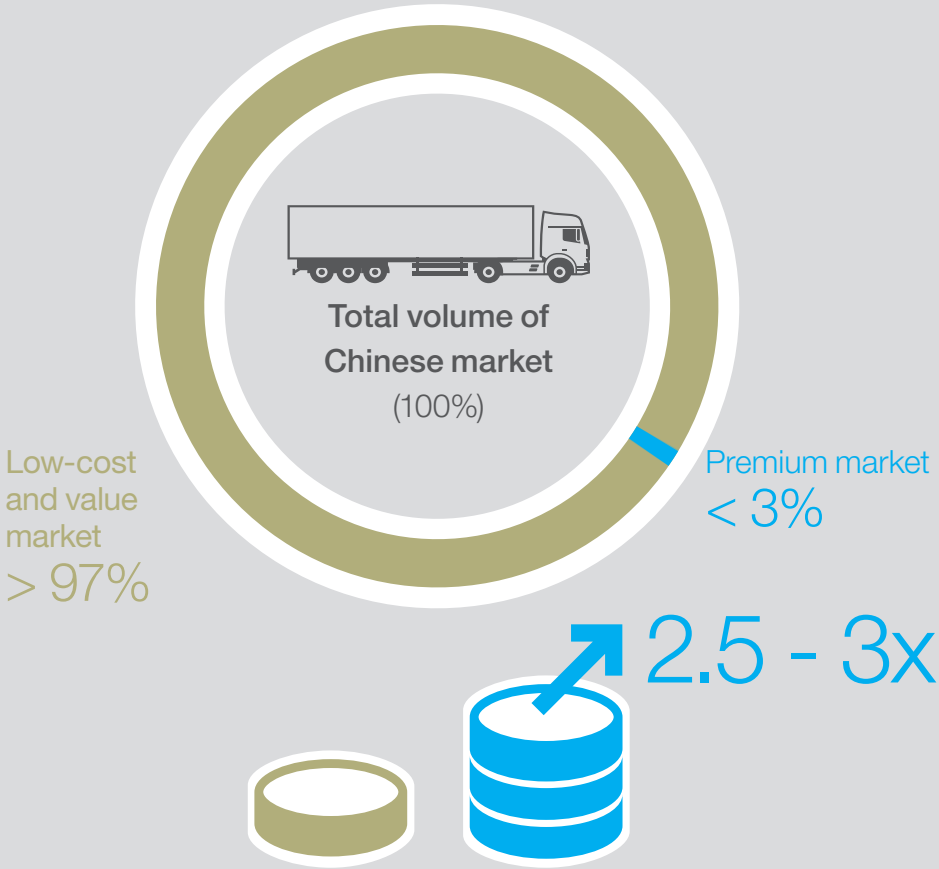


Truck specifications and performance have risen faster than the prices for these products for a simple reason: fierce competition. The long period of rapid volume expansion in the market led OEMs to focus on securing capacity to meet the seemingly ever-growing demand. Now that demand has dried up, the many local makes are competing for their slice of a pie that is only ~ 40 percent of their aggregated production capacity.

This dynamic explains why truck buyers have pocketed most of the benefits from product improvements. Intense competition has prevented OEMs from pricing these improvements into the market. Not surprisingly, the profitability of Chinese truck makers has diminished as a result.

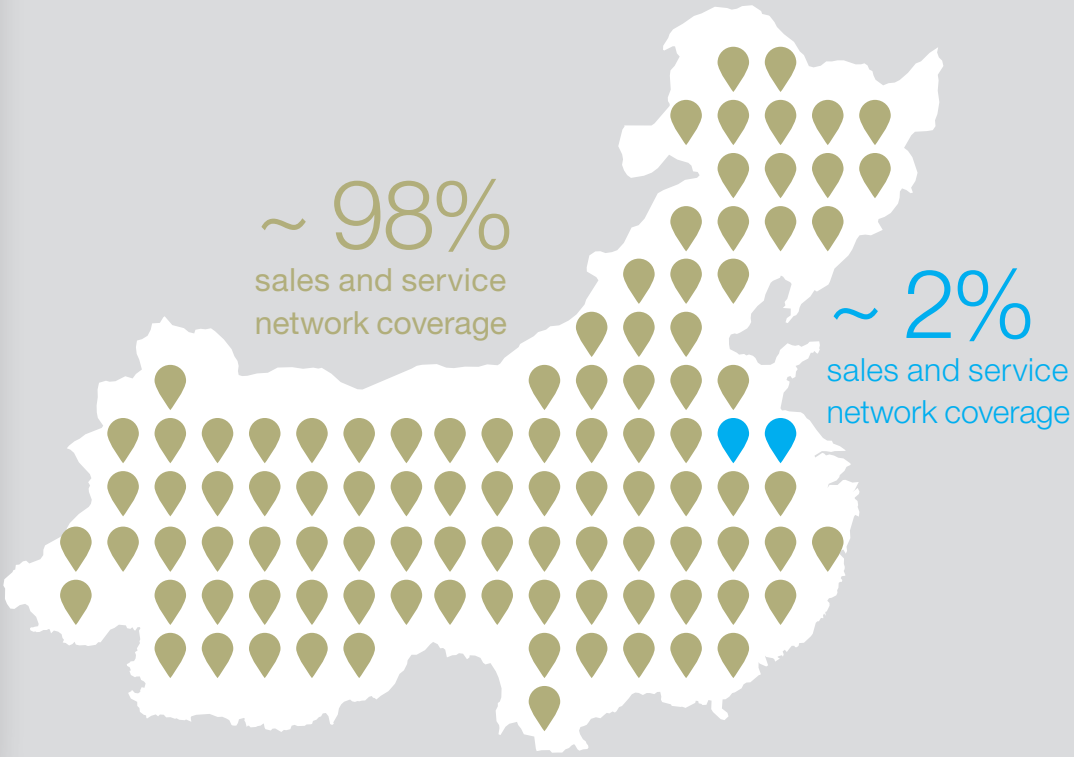
Obstacles to the competitiveness of imported premium trucks

The market's premium share is very small



Price of premium trucks often being 2.5 - 3x as high as those of local makers

Premium makes also suffer from their more limited sales and service network coverage



Imported premium trucks face many obstacles in the Chinese market. Today, a premium truck generally costs 2.5 to 3 times more than one from a local manufacturer, yet most customers do not perceive a corresponding advantage in performance or quality. In addition, import makes suffer from their more limited sales and service network coverage. Although imports are still well ahead of local makes in terms of product quality and reliability, the uptime and reliability perceived by customers is often quite similar. In the words of one customer, "Even though the premium trucks may break down only once or twice a year, when they do it can take a week to get them back on the road – instead of one day for a Chinese truck." Consequently, the widely anticipated growth of the premium market has not materialized, and premium trucks still account for less than 3 percentage points of total truck volume in China.

What can we expect from the Chinese truck market in the long term (2025 - 30)?

In the long term, the customer and supply structure of the Chinese truck market is likely to become more similar to that of Western markets. The pace and magnitude of the shift, however, remain uncertain. The answers to several questions will determine what the market looks like 15 years from now:

- How fast will the transport company landscape consolidate?
- Will the producer landscape consolidate down to four to five major Chinese OEMs, and which ones will they be?
- What will be the role and influence of these companies' Western joint venture partners?
- Will Chinese truck makers be able to continue closing the gap to Western imports in terms of specifications, performance, and quality?
- Will they be able to do so without increasing product cost – and thereby pricing – in an environment where labor and material are becoming more expensive?
- Who will ultimately win the price/performance race in the Chinese truck market – and at what price levels?

These developments are worth watching: depending on the outcome, the Chinese truck market could eventually emerge as a major premium truck market where manufacturers from all over of the world compete head-to-head.

Deep dives on key industry topics

II. Modular strategy

How we look at it and typical impact

Successful modular strategies incorporate 3 lenses in order to find the sweet spot

Overall we've seen impact typically in the range of 15 - 30% in product cost reduction (over lifecycle) in low- and high-volume business

I Managing internal complexitiy through platform and modular components

II Managing external complexity via product portfolio

III Realizing and sustainably anchoring complexity management

Variable product costs

Inventories	30 - 50%
Logistic costs	10 - 40%
Manufacturing costs	10 - 30%
Material costs	5 - 10%

Product invests

R&D	30 - 70%
Plant equipment invest	10 - 50%
Testing and certification	0 - 40%
Tooling invest	10 - 30%

Nonregular product costs

Delays and penalties	Up to 75%
Quality costs	0 - 70%
Supply safety	20 - 50%

Top-line effects

Time-to-market	30 - 70%
Innovation rate	10 - 50%
Coverage of niche segments	0 - 40%

Cost savings of 15 - 30%

Effectively managing complexity has become a key mandate for business success. In the past, consumers looking to buy products from automobiles to appliances may have been satisfied with just a handful of choices. Today, however, few companies can survive with such a basic product portfolio. The shift has been dramatic. An automotive OEM that once sold 6 compact models now lists 17 different compact class vehicles. In an even more extreme example, the number of mobile phones offered by a major electronics company exploded from 5 in 1990 to more than 180 – with a vast range of specifications, features, and geographic variants – in 2013.

However, rapidly growing product portfolios and increasingly global markets are not the only factors driving the complexity boom. Products themselves have also become more complicated as companies offer more features and options. When faster innovation cycles that complicate portfolios and more intricate aftermarket parts management are added, the complexity soon begins to seem overwhelming.

This web of new complexity drivers has repercussions beyond increased complexity itself. Since most traditional accounting systems do not fully capture the complexity costs that result, niche products often seem more profitable on paper than they really are – and can drag down the profitability of the entire business. While complexity management is essential to success, it is not a business objective in itself. A good business strategy needs to find the "sweet spot" between two extremes: a market-driven product portfolio with a differentiated offering for all customer groups and market segments on the one hand and clear, organization-wide standards to ensure the effectiveness of internal processes on the other. For truck manufacturers today, a modular approach to product development and production is the key to achieving this balance.

A modular strategy supports the entire organization in managing complexity:

- "Upstream" functions, such as product development, sourcing, supply chain, and production, can better ensure optimal synergies between the different products (i.e., manage internal complexity). This includes managing the re-use of common parts, designing product architectures with clear interfaces that allow for plug-and-play configuration, and developing supply chain processes that bundle effective production of standard modules with a highly responsive, make-to-order assembly process.

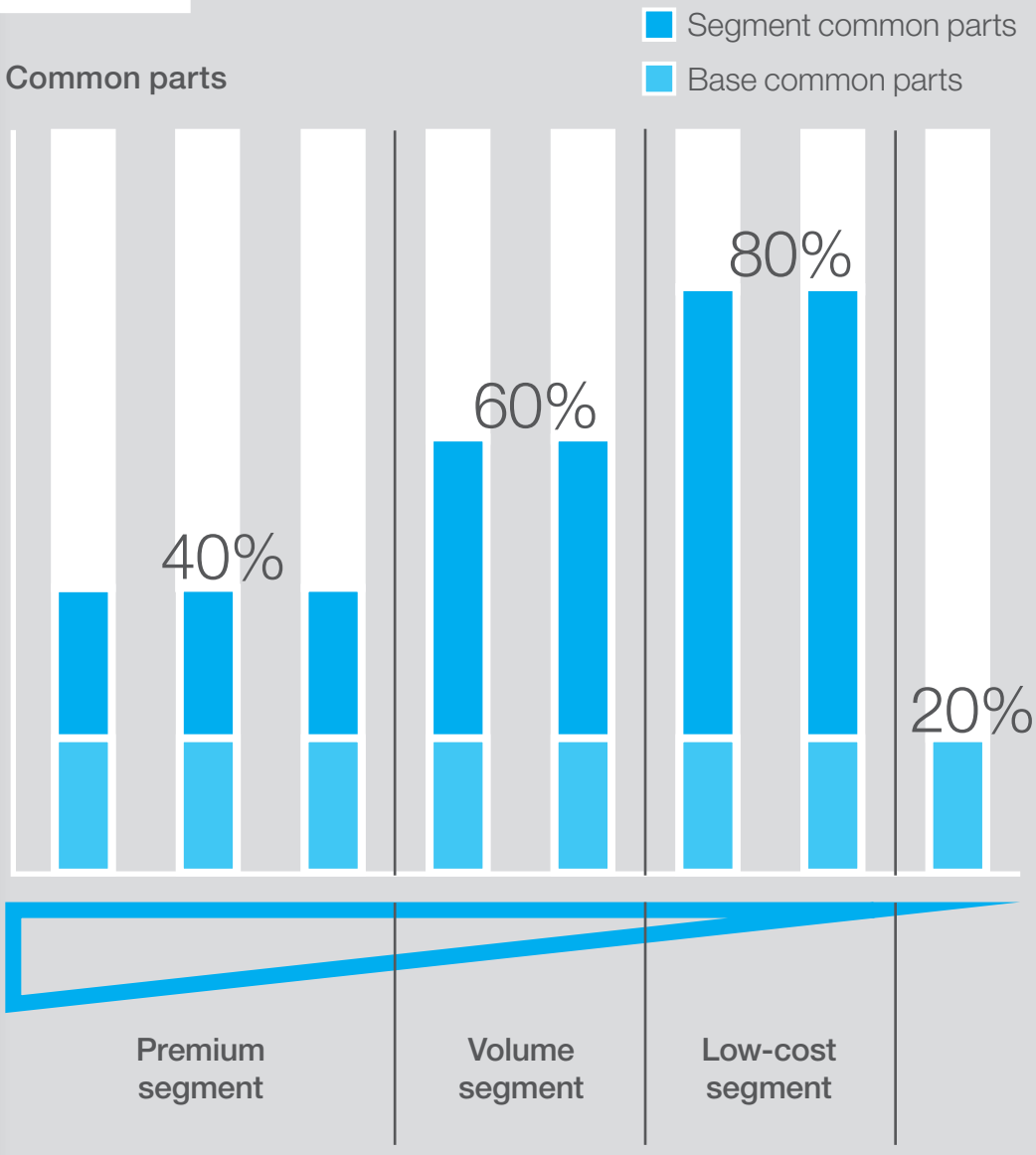
- At the same time, the "downstream" functions (sales, marketing, services, aftersales) can more effectively manage the portfolio of offerings (i.e., external complexity). Modular approaches enable them to ensure adequate levels of product differentiation and better manage complexity costs, order lead times, and effective pricing of options in their planning processes.

- Work does not stop once these efforts are successful. Complexity levels across the portfolio need to be constantly and effectively monitored and measured (i.e., complexity management needs to be realized and sustainably anchored), as product complexity has a strong tendency to creep back in. But companies that manage this balance well have seen cost savings reach 15 to 30 percent over their product lifecycles.

Managing internal complexity

I
Internal

Successful implementation at agricultural machinery showed great impact on internal product complexity ...



... from low-cost segments (standard entry product) to premium segment (high-end platform)

Key success factors

- Integrated long-term planning
- Differentiation and levels of standardization
- Comprehensive cross-functional effort
- Fact-based decision making

Case example

While standardization is desirable, it cannot be a one-size-fits-all activity. The optimal level of commonality between products depends on the differentiation needs of those products, the profitability of the segment, and production volumes.

One agricultural machinery manufacturer takes a two-tiered approach. The target level of standardization is much higher for its low-cost segments, where intense cost pressure and high production volumes meet customers who more or less look for commodity/retail products. Products for the high-end market are more sophisticated and require much more differentiation, and margins allow for this.

As a result, the company has designed distinct platform architectures. Just as passenger car OEMs create different platforms for large and compact vehicles, the machinery company technically differentiates its platforms by market segment. Price considerations justify differentiation along this dimension. For example, it would be impossible to set prices for premium products that are 2 to 3 times higher than those for entry-level products if platforms were designed to have 80 percent of their parts in common.

Key elements of optimal standardization

Integrated long-term planning

Integrated long-term planning. Companies should take a long-term, forward-looking perspective regarding modular architectures instead of pursuing an opportunistic, one-off reuse of parts across products. They should fully integrate platform and module development into a broader product portfolio strategy and planning framework over time, setting clear milestones for key product events such as new launches and/or facelifts over the entire product cycle.

Differentiation and levels of standardization

Differentiation and levels of standardization. Teams need a very explicit understanding of the sources of product or regional distinctiveness, which they typically develop by working hand in hand with the marketing and sales function. Differentiating specific components to reflect a product's unique selling proposition (USP) requires companies to establish clear guidelines for future development.

Comprehensive cross-functional effort

Comprehensive cross-functional effort. This approach moves beyond standardization alone to employ a broader set of cross-functional modularity tools and techniques.

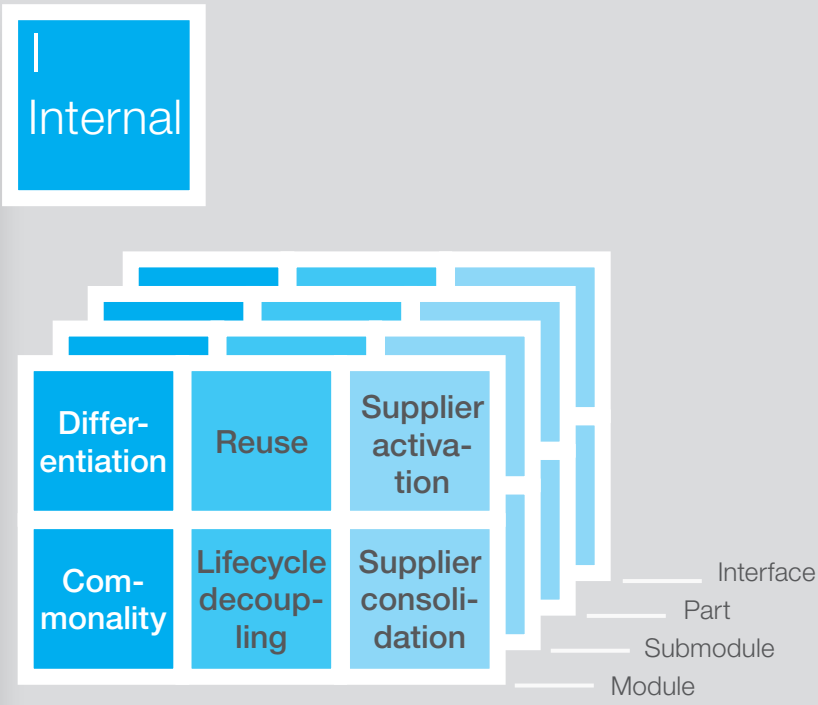
Fact-based decision making

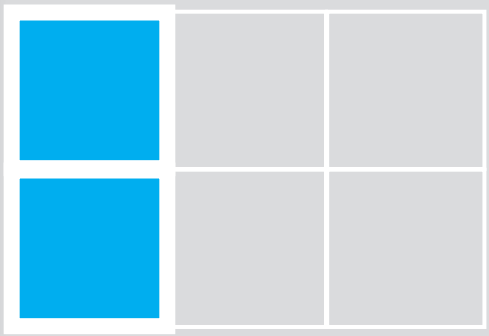
Fact-based decision making. Experience shows that it pays to overinvest up front in data transparency so that teams can drive modularity decisions based on facts rather than opinions or gut instinct, which can lead to bad decisions.

Deep dive on success factors

Modularization is not only about commonality – different levers have to be applied together …

… and these need to be pulled in a systematic approach (from-to examples)



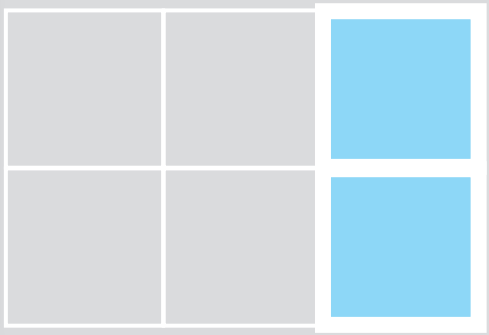


Unsystematic approach
Same instrument panel in different cars

Systematic approach
Differentiation between visible and invisible components: differentiation of visible parts on the surface, and commonality of invisible parts “behind the scenes”

Unsystematic approach
Reuse of instrument panel from one generation to the next

Systematic approach
Lifecycle decoupling of seat control units: definition of standard space enables application of latest equipment across all modules (~ 30% price reduction every 3 years)



Unsystematic approach
Engine-specific development of a fuel injection system (sourcing on system level)

Systematic approach
Intensification of competition on sub-module level: break-up of fuel injection system and standardization of specifica-tions enable new sourcing

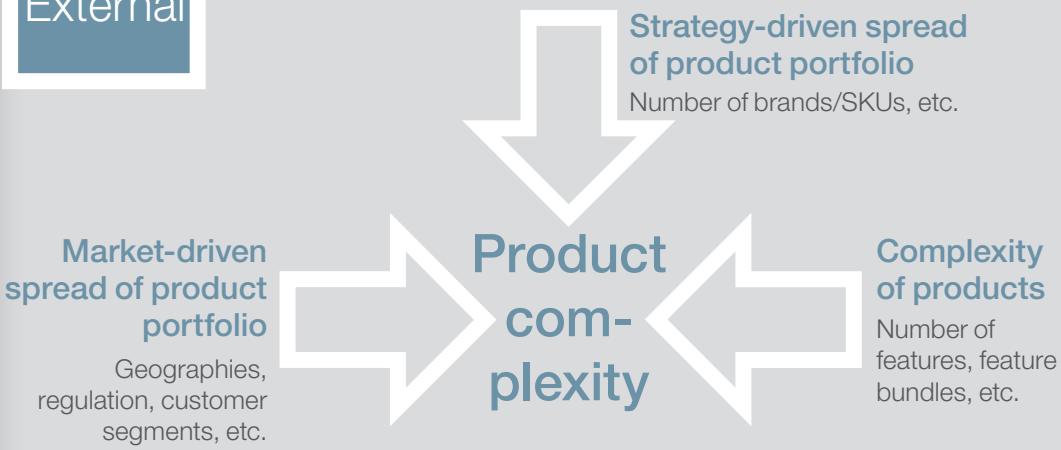
Implementing a successful modular strategy at the product level requires moving beyond the typical approach of simply classifying parts as common or differentiated. Products and platforms usually have a long lifecycle in the truck industry, so OEMs have to dig deep. From the pure module or component level down to interfaces and specification descriptions within products – the challenge for truck manufacturers is to find and pull the right levers at the right level.

Examples include decoupling lifecycles (for example, of electronics for customer interfaces/controls vs. for infotainment systems) or reviewing sourcing strategies with the procurement function to boost scale effects or break up supplier monopolies. One truck manufacturer established dual sourcing for a fuel injection system by standardizing the design specifications.

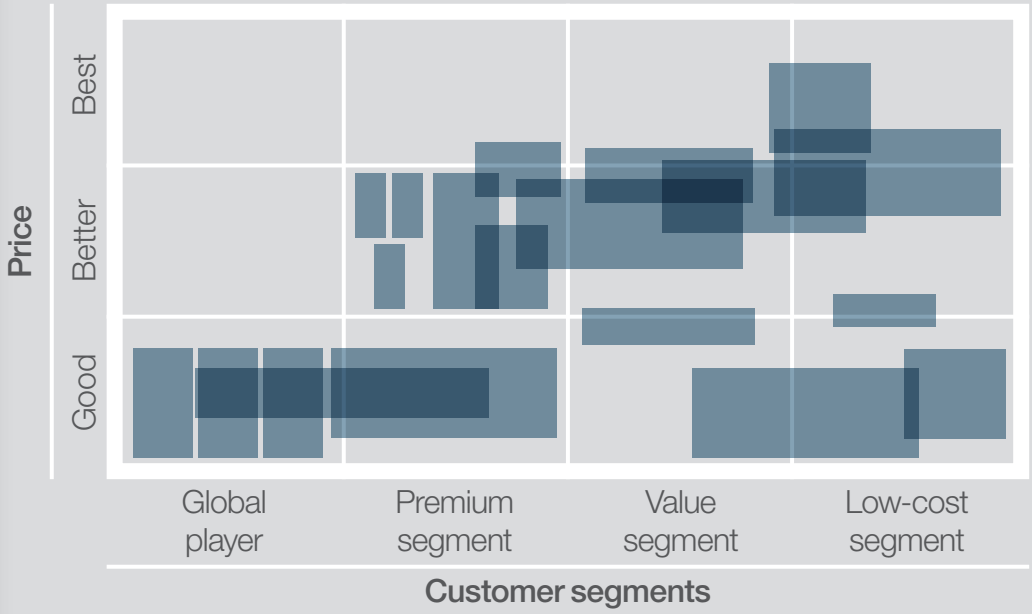
Managing external complexity

II External

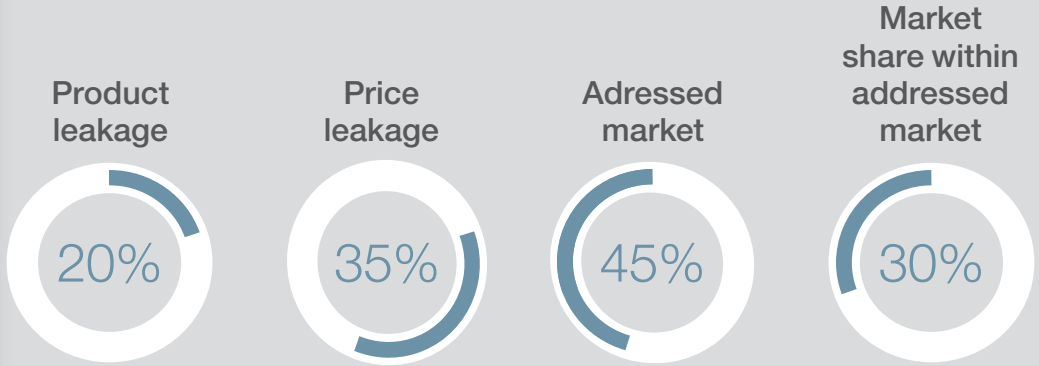
3 external forces with high impact on product complexity



Market-driven spread of product portfolio within market coverage and price-performance mapping



Example: dissecting product/price leakages from market share performance helped to optimize strategy-driven spread of product portfolio



When thinking about a modular strategy, the most obvious places to start are the design of products and the architecture of platforms. As we have seen, tackling these areas can bring big benefits. However, this approach only addresses complexity that OEMs generate internally, based on their desired market coverage and the resulting spread of their product portfolio.

Customers themselves are becoming more complex, too, and market competition is pushing up the requirements on manufacturers regarding the features they offer and the differentiation in their product portfolios. Understanding this "external complexity" is a must, especially for manufacturers with more than one brand. Not only does it ensure that the OEM is meeting customer needs, but it can also guide modularization efforts. For example, mapping a manufacturer's products against market coverage can identify white spots the company needs to fill. At the same time, it can reveal overlap between existing products and feature offerings. Equipped with insights from such a "broader view," management can reassess the product architecture and optimize the underlying modular strategy, narrowing the number of options offered to respective customer groups.

Considering external complexity helped one industrial equipment manufacturer devise a new modular strategy for its products. The company had focused on the Western European premium market when developing its product portfolio. As a result, it was underperforming in some key fast-growing markets where customers were generally most interested in low-cost products.

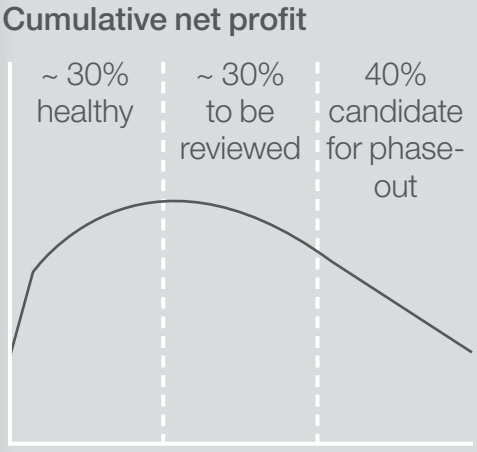
Deriving product portfolio gaps from its market share performance enabled the company to define product standardization initiatives for the different regions where it does business. Market share increased by 5 percentage points as a result, and this improvement was seen as key driver for revenue growth of USD 2.6 billion.

Deep dive on complexity of products

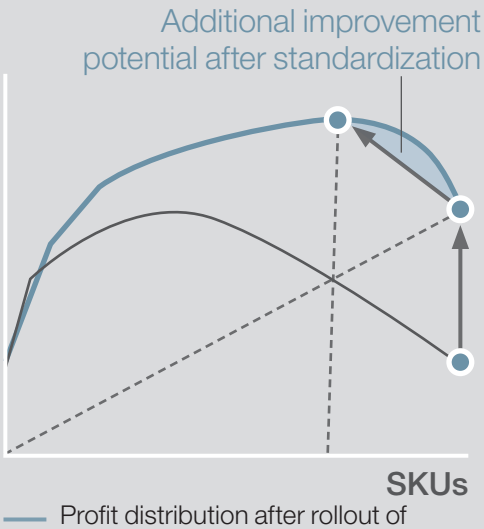
II External

Typically, financial systems do not account for fair allocation of overhead and complexity cost

Cumulative net profit accounting for fair allocation of overhead and complexity costs



Impact of internal complexity management on the cumulative net profit



Example: SKU reduction via feature/ configuration bundling through data-driven approach

18% of customers have configured option B, only 8% have bought it. Most customers have upgraded

Configuration option	A	B	C	D	Total configuration
A	15%	2%	4%	1%	22%
B	2%	4%	8%	4%	18%
C	0%	1%	28%	3%	32%
D	0%	1%	2%	25%	28%
Total purchase	17%	8%	42%	33%	100%

Allocating complexity (costs) fairly to reduce the product portfolio

Traditionally, complexity costs (primarily consisting of one-time costs for niche products) are allocated based on sales. In this approach, long-tail products and configurations – in other words, those with smaller unit counts – generally show a profit just as high runners do. But there is a catch: sales-based allocation does not accurately reflect the actual cost of long-tail offers. As a result, niche products appear more profitable than they really are and end up "freeloading" off their high-runner counterparts. The picture changes when truck makers identify what drives costs and appropriately allocate costs to unit counts. In a fair allocation approach, many long-tail configurations are unmasked as loss makers.

Purely internal efforts to reduce complexity can help to lift the curve, but in most cases they leave manufacturers with products that still do not make a profit – or deliver weak returns that do not justify the cost of a platform migration. Intelligently structuring the product offering based on customer segmentation and big data analysis of customers' configuration and purchasing behavior can weed out these unprofitable products.

Customers can be divided into clear segments based on the engines, lines, and special equipment they select. Within each segment, their behavior is highly predictable. As a result, manufacturers can simplify and structure the choices available to them by offering packages, providing some equipment exclusively with certain packages, and managing the options available in the configurator. Such segmentation and structuring pays off by lowering complexity and increasing the average share of wallet per customer. Within this segment-focused structure, truck makers can take advantage of customers' upgrade behavior to optimize equipment offers with standard and premium versions, such as infotainment and telematics systems.

Segment patterns remain consistent across both countries and models, creating opportunities to reduce production and development complexity as well. All in all, truck makers can greatly increase their share of customers' wallets and lower complexity, especially for higher-quality models they are less likely to offer as special model versions.

III
Realize

How to achieve sustainable impact

In the enthusiasm stirred by early modularity successes, companies often underestimate the effort required to establish it strongly. For example, making sure the company's IT infrastructure can codify and manage common part numbers on schedule is a "must have" element of any plan to implement and measure modularity improvements. If not addressed in a timely manner, it can significantly slow down and endanger the program's success, hindering engineers' efforts to identify the correct common parts to use, for instance.

From the organizational point of view, mastering modularity will require a deep and complex transformation when it comes to roles, responsibilities, and product development practices. Consequently, organizations cannot approach it as a one-off project. While there may not be a one-size-fits-all organizational model, companies can still identify a set of common elements. These relate to the development and application of modular solutions across families of products and platforms, the coordination of the innovation cycles in the broader company portfolio strategy, and the need to guard the achieved commonality levels and avoid a resurgence of complexity.

Organizations typically address these requirements by appointing central module managers. An automotive OEM might assign a "Rear Axle Module Leader," while a telecommunications cell phone OEM might hire a "Display Technology Champion." These managers coordinate the company-wide portfolio of variants, define specifications for common parts, and act as complexity guardians for their systems. They also work closely with platform and project managers to ensure the best trade-offs are made between modularity and product-specific requirements.

Why success requires top management attention

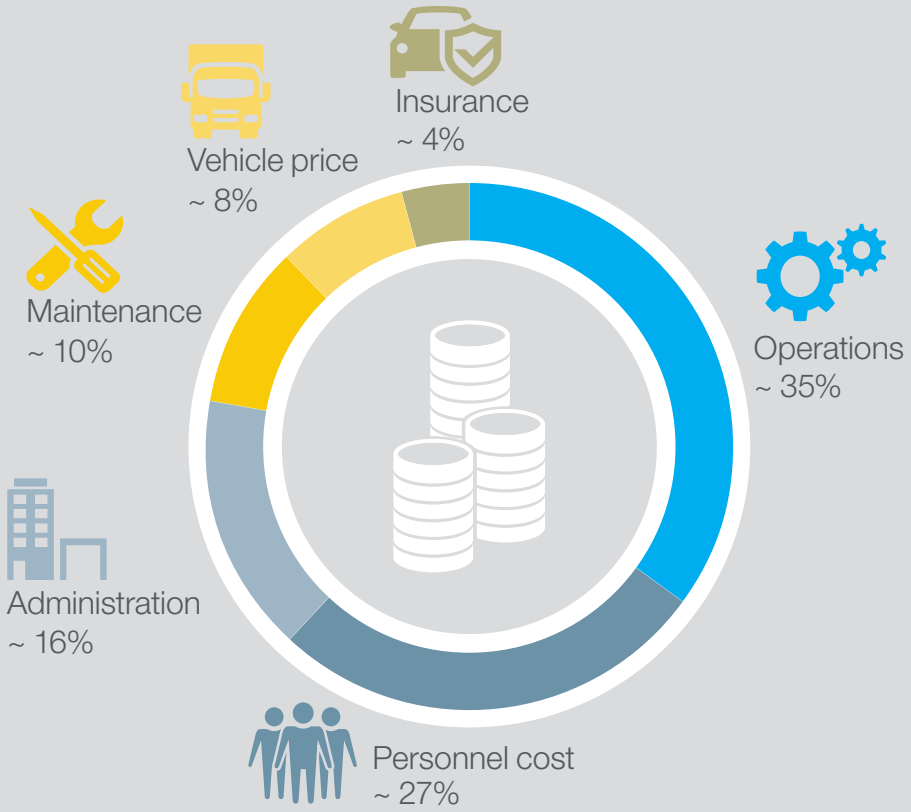
In addition, top management commitment is a pre-condition to success. The journey to modularity requires a broad, cross-functional effort that involves a significant mindset change and requires a systematic approach. The most successful experiences, especially when companies launch their very first modularity initiatives, involve company-wide assemblies where top managers openly discuss the opportunity to launch such a program and the expected benefits and risks. These communication campaigns, especially when they involve a deeply committed CEO and top managers in program status reviews, help to confirm the cross-functional nature of the effort and demonstrate the role modeling required to sustain the change.

Deep dives on key industry topics

III.A
New service and business models

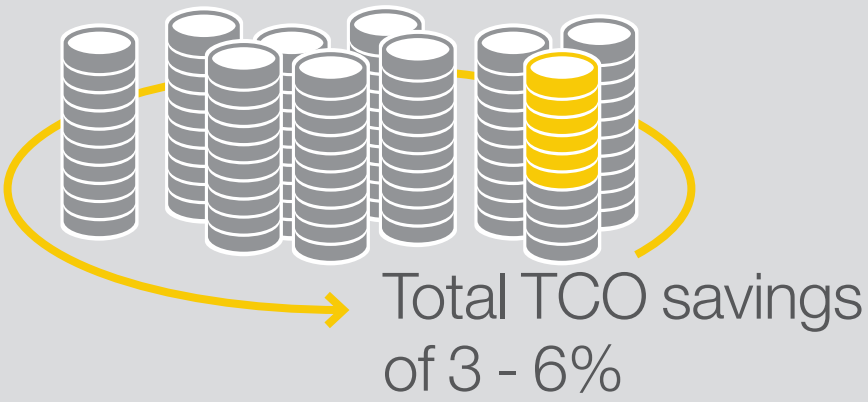
The impact of new services on the elements of TCO

Total cost of ownership (TCO) today



Estimated change in TCO through new service and business models

Significant TCO savings potential



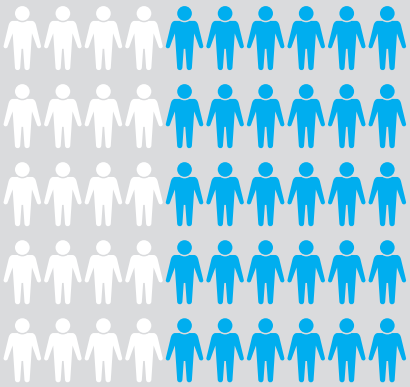
New, connectivity-enabled business models are transforming the medium-sized and heavy-duty trucks market by increasing safety, driving down the cost of ownership, and adding a never-before-seen level of convenience for owners. These business models affect virtually all aspects of ownership and operation – from automated driving to telematics-based fleet management services – and involve all stakeholders, including manufacturers, customers, regulators, financial services institutions, and telecommunications operators.

While many stakeholders have a role to play in the new, connectivity-enabled services, customers and truck manufacturers are among those with the most to gain.

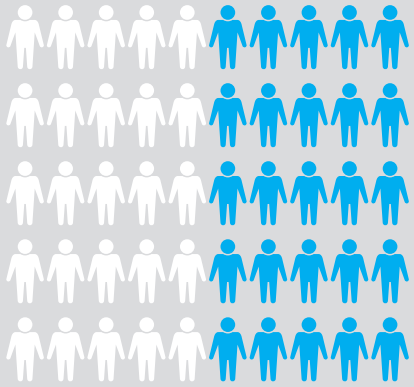
Connectivity and remote services have the potential to significantly reduce the total cost of ownership (TCO) of medium-sized and heavy-duty trucks. While these services will likely increase a unit's purchase price by about 10 percent, this cost is offset by the fact that the purchase price is one of the least significant contributors to TCO. Costs related to maintenance, operations, personnel, and administration generate the largest share (> 80 percent of a truck's TCO, see infographic). Remote diagnostic services can help reduce maintenance costs by 5 to 10 percent, and real-time traffic information can deliver similar savings in the operations category. Combined, connectivity-enabled services in these categories and others can yield total TCO savings of 3 to 6 percent.

Market research on the use and expectations of apps in cars

Customers are even more interested in vehicle management applications than in entertainment



~ 60%
of customers are interested in vehicle management applications



~ 50%
of customers are interested in entertainment applications

Use of smartphones is up

~ 28%
of German drivers use smartphones in the car

~ 70%
use their phones for purposes other than calls

Personal data is becoming increasingly available

~ 67%

of the 18- to 39-year-olds expect that personal data from social media platforms will be available in cars in the next 10 years

Customers are willing to pay a premium

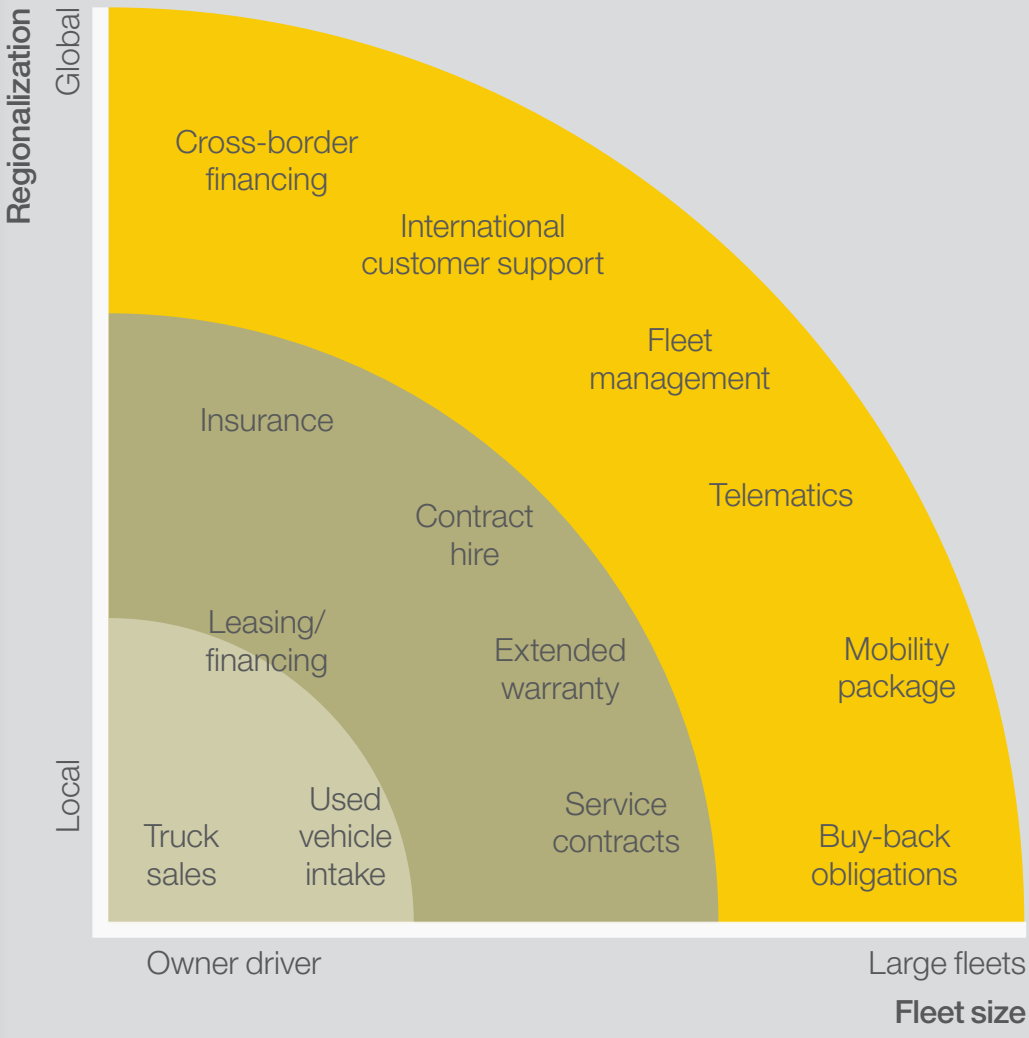
~ 50%

of car drivers expect to pay an increased vehicle price due to connectivity-enabled services being included in the future

Market research indicates that now is the time for heavy-truck manufacturers to create and offer segment-specific value propositions in the area of connectivity-enabled services. Services that leverage personal data to enhance the driving experience offer significant revenue potential. Furthermore, customers increasingly expect these services and are willing to pay for them – thus creating a context in which this potential can be unlocked

Products and services demand by fleet size and regionalization

Connectivity-enabled products and services



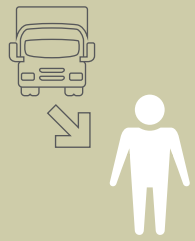
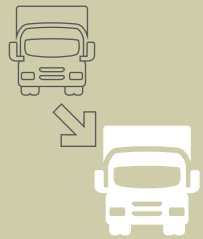
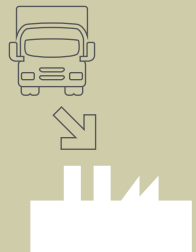
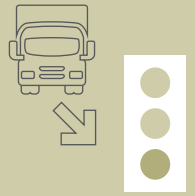
Truck OEMs can enlarge their portfolios through innovative products and services and potentially become fully integrated service providers

Cost efficiencies are just one driver of customer demand for connectivity and remote services. These services also offer a level of convenience and peace of mind, and automotive research reveals that not only are customers comfortable with this digital-driven convenience, they increasingly expect it. Customers across the size and footprint spectrum value connectivity's upside, from the possibilities for greater international support for cross-border fleets to ease of sale/purchase for the individual owner.

Manufacturers see the business opportunity that connectivity presents. First, there is revenue potential from the higher vehicle sales price that comes with additional features and ongoing aftersales services. Second, offering the digital innovations of connectivity-enabled services is an opportunity for truck manufacturers to strengthen their brands. Third, these services generate new types and high volumes of customer data, which manufacturers can leverage to sell additional, highly-tailored offerings and retain satisfied customers.

Connectivity-enabled service by type and application

Connectivity-enabled product and service offering unlocks a variety of use cases

Type of communication	Applications: Driving assistance/ automated driving	Applications: Infrastructure services
Truck to driver 	Parking assistance	
Truck to truck 	Pre-collision warning	
	Traffic jam assistant	
	Platooning	
	Automated obstacle avoidance	
Truck to transporter/ transport buyer 	Customized OEM add-ons	Track-and-trace function for fleet management
		Optimization of routing
		Real-time freight data (cooling temperature, etc.)
		Fuel theft protection
Truck to infrastructure 	Automatic emergency call (e-call)	Optimized signal timing and traffic flow (avoiding traffic jams)
		Electronic tolling
		Interconnected parking

	Vehicle relationship management	Driving behavior feedback	In-truck content/services
	Theft protection	Live warning for inappropriate driving	Augmented reality through windshield with routing information
	Remote unlock/lock, horn, cooling/heating	Real-time information on fuel consumption and how to improve	Transfer of “last mile” information to smartphone
	Remote truck steering		In-truck app eco system
			Access to native apps and smartphone-integrated apps
			Tracking of multiple trucks to drive in convoy
	OEM-exclusive repair shop finder	Reporting of performance to fleet owner	Reliable predictive traffic information
	Notification for (preventive) maintenance appointment in workshop		Location-based services
	Extended emergency assistance		Map updates
	Stolen truck tracker		Web access
	Direct mobile payment		
		Handling- and usage-based insurance tariff	Optimized signal timing and traffic flow
			Environmental and roadway monitoring

Benefits of connectivity-enabled maintenance and repair services

Various kinds of upside potential for OEMs and other service providers

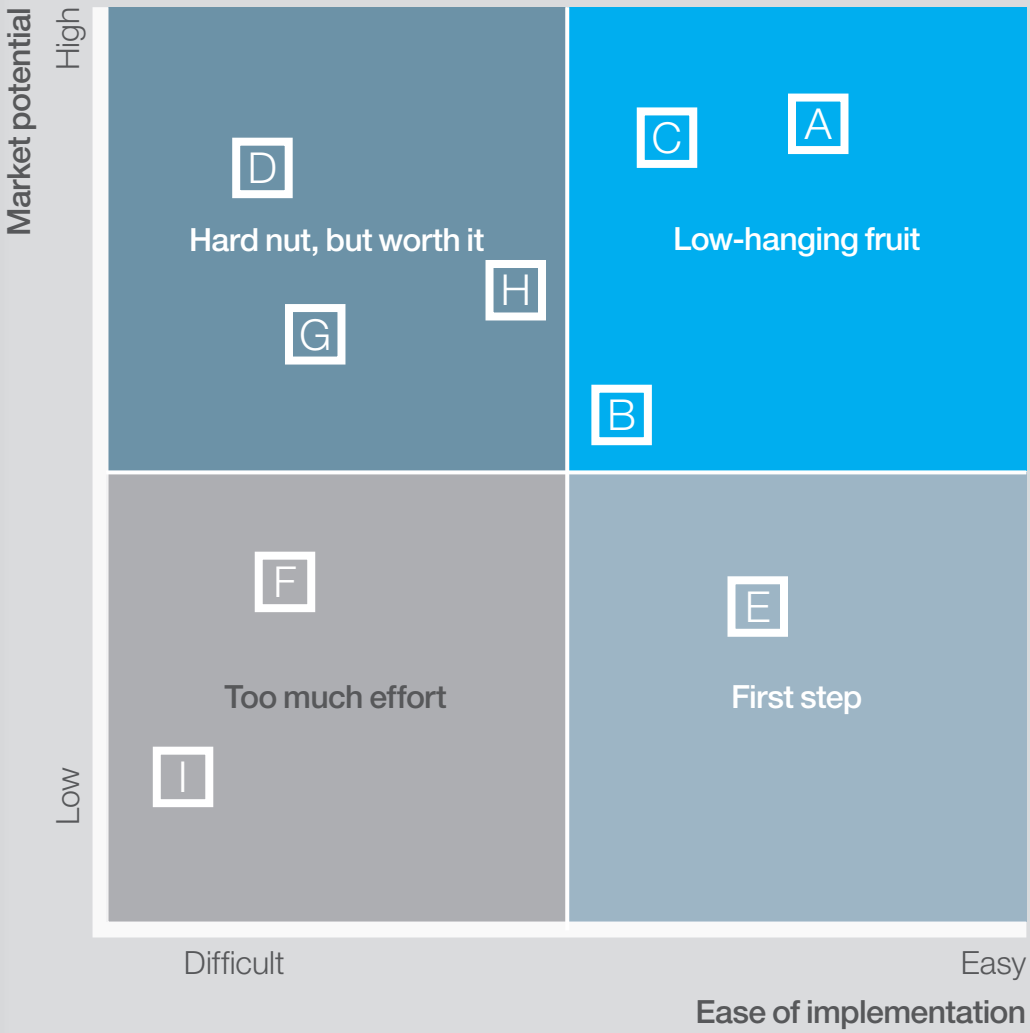
Revenue focus

- A Optimization of customer contact and loyalty
- B Offers tailored to specific customer segments
- C Reduction in "lost sales"
- D Innovative service products
- E Cooperation models
- F Optimized pricing

Efficiency focus

- G Excellence in supply chain and repair shop processes
- H Preventive/predictive maintenance
- I Systematic analysis of overall pool

Assessment regarding ease of implementation and market potential (company dependent)



For a better understanding of the various kinds of upside potential for OEMs and other repair and maintenance service providers in the truck business, it may be helpful to provide concrete examples for the relevant levers and distinguish between levers with a revenue focus and those with an efficiency focus.

First, here is a list of the six levers with a revenue focus, including a short description of what each of these entails:

A Optimization of customer contact and loyalty through increasing (service) loyalty with direct contact, e.g., proactively suggesting maintenance appointments

B Offers tailored to specific customer segments through using more precise customer segmentation to create product offerings for specific needs, e.g., with cross-selling or "packages"

C Reduction in "lost sales" by ensuring high parts availability and, thus, reducing the incentive for customers to go to another repair shop

D Innovative service products through introduction of innovative telematics-enabled services

E Cooperation models with the use of telematics infrastructure and data for external partners, such as fueling stations and insurance companies

F Optimized pricing, e.g., specific products in each region, enabled by big data.

Second, here are the three levers with an efficiency focus:

G Excellence in supply chain and repair shop processes through improvements in, for example, demand forecasts for spare parts, leading to lower inventories and more targeted repairs

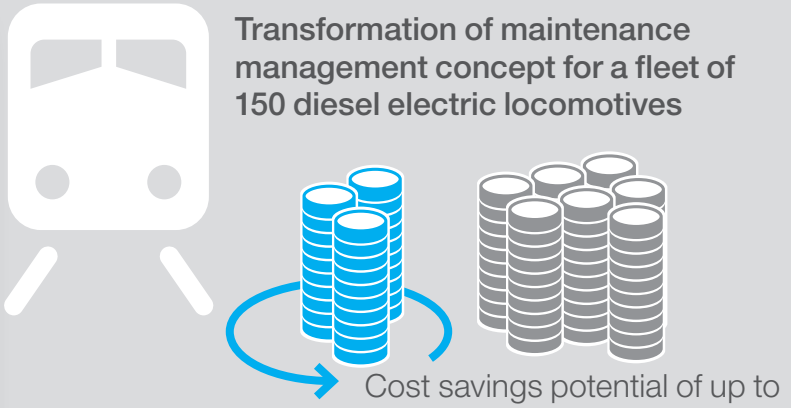
H Preventive/predictive maintenance by diagnosing problems remotely based on historic maintenance data (preventive) or sensor-data-based data (predictive) to eliminate them before they lead to greater damage

I Systematic analysis of overall pool can keep "surprise" problems minimal, especially those involving new developments.

Example: cost impact through preventive maintenance

Example from the train industry

Transformation of maintenance management concept for a fleet of 150 diesel electric locomotives



Cost savings potential of up to **30%** of total maintenance cost

How it works

Input → Analytics → Output

Input

- Central sensor data (pressure, temperature, mileage, etc.)
- Technical data (age, energy consumption, etc.)
- System data (work orders, inventory transactions)
- Experience from personnel

Analytics

- Data cleaning
- Combination of data sources
- Segmentation of failures
- Statistical analysis

Output

- Comparison with known failure patterns and rates
- Optimization of component-specific maintenance approaches and intervals

What it needs to make it happen

- **Central database** with sufficient failure samples
- Sufficient vehicle **data quality**
- **Analytical models** for failure patterns, rates, and dependencies
- **Easy-to-read evaluation** of results
- Derivation of **recommended service patterns**

Broad agreement exists that new, connectivity-enabled business services are perceived as value-adding to customers, in terms of savings and convenience, and value-creating for manufacturers, with regard to revenue. In fact, connectivity-enabled services have already been introduced by the overwhelming majority of truck fleets. The incongruence comes when we look at the degree to which services are being implemented. Remote services for preventive maintenance, connected service pricing, and connected spare parts supply chains, for example, are, so far, being used by only a small share of manufacturers.

It also seems increasingly clear that connectivity proliferation will no longer be just a "nice-to-have" industry add-on but a disruptive force. Among other shifts, autonomous driving technology may move the responsibility for accidents from the driver to the manufacturer, and remote diagnostic services may make some in-person maintenance services obsolete. Losing out on potential revenue and customer retention gains may be just the tip of the iceberg for manufacturers who are slow to adopt the new, connectivity-enabled business models.

Deep dives on key industry topics

III.B Opportunities through telematics

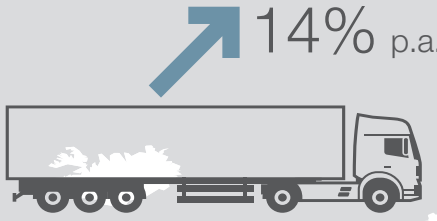
Telematics will boost several automotive revenue pools by 2020

Telematics technology is expected to become standard automotive equipment by 2020

Source: Frost & Sullivan, 2014

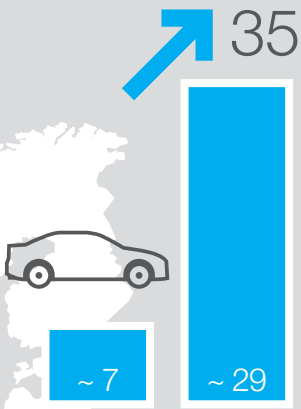
Total number of fleet management systems installed in commercial vehicles in Europe

Millions



Passenger car telematics units sold in Europe

Millions



99%
penetration of Europe's new truck market in 2020

98%
penetration of Europe's new passenger car market in 2020

Telematics technology will likely unlock several significant automotive revenue pools

Application	Volume of revenue pool 2015 EUR billions	2020 EUR billions	CAGR 2015 - 20
Fleet management	3.3	8.0	↗ 19%
In-vehicle emergency call system	0.3	1.8	↗ 43%
In-vehicle entertainment and Internet access	1.7	10.0	↗ 42%
In-vehicle voice	0.1	0.3	↗ 37%
Lease, rental, HP, and share car management	0.9	2.5	↗ 23%
Roadside assistance	1.5	9.1	↗ 43%
Stolen vehicle recovery	6.0	27.2	↗ 35%
Usage-based insurance	2.6	12.7	↗ 37%
Vehicle diagnostics	2.1	13.0	↗ 44%
...	...	...	...

Source: Machina Research, 2015

Telematics technology and telematics-based applications are already widely available and play an important role for commercial trucks. By 2020, it is expected that these technologies will be present in almost 100 percent of all new commercial vehicles and private cars sold.

With the technology becoming standard automotive equipment, ever larger revenues are going to be generated from service offerings that rely on telematics technology for connecting the vehicle with the driver and the service provider. This opens up multiple opportunities for increasing customer value beyond the simple functioning of driving a car or basic product transport.

The significant increase in new automotive revenue pools unlocked by telematics-based applications results from a wide range of service offerings that can be expected to experience strong growth within the next five years. Among others, these applications include:

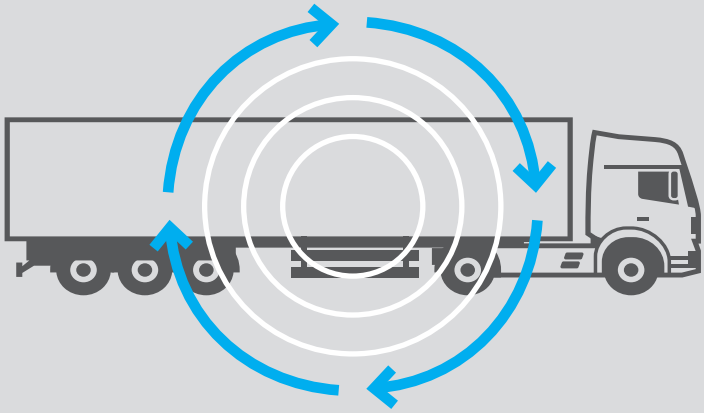
- Fleet management, i.e., telematics technology-based systems and services for businesses – e.g., for car rental companies and car sharing providers – that facilitate information exchange between a commercial fleet and the dispatching office
- In-vehicle emergency call systems that automatically call the national emergency hotline (e.g., 911) in case of a serious road accident and simultaneously transmit GPS location data to local emergency services
- In-vehicle entertainment and Internet access, i.e., navigation, multimedia, social media, and in-vehicle Wi-Fi connection
- In-vehicle voice that offers telephone or even concierge services to drivers
- Lease, rental, HP, and share car management that is used for mileage capture, expense management, vehicle administration, environmental monitoring, etc.
- Roadside assistance that helps drivers with a mechanical failure, who would otherwise be stranded
- Stolen vehicle recovery that tracks and locates a stolen vehicle and notifies the police of its precise location for recovery
- Usage-based insurance that can be used for dynamically adjusting insurance cost through exact measurement of driving behavior and customer feedback
- Vehicle diagnostics, i.e., on-board telematics that monitor a vehicle's performance in real time and alert the driver (and potentially maintenance services) of potential problems with the engine, for example.

Creating a connected truck offering requires a specific process

Business planning for a new connected truck offering should follow a 4-step process

Need
Understand the customer needs

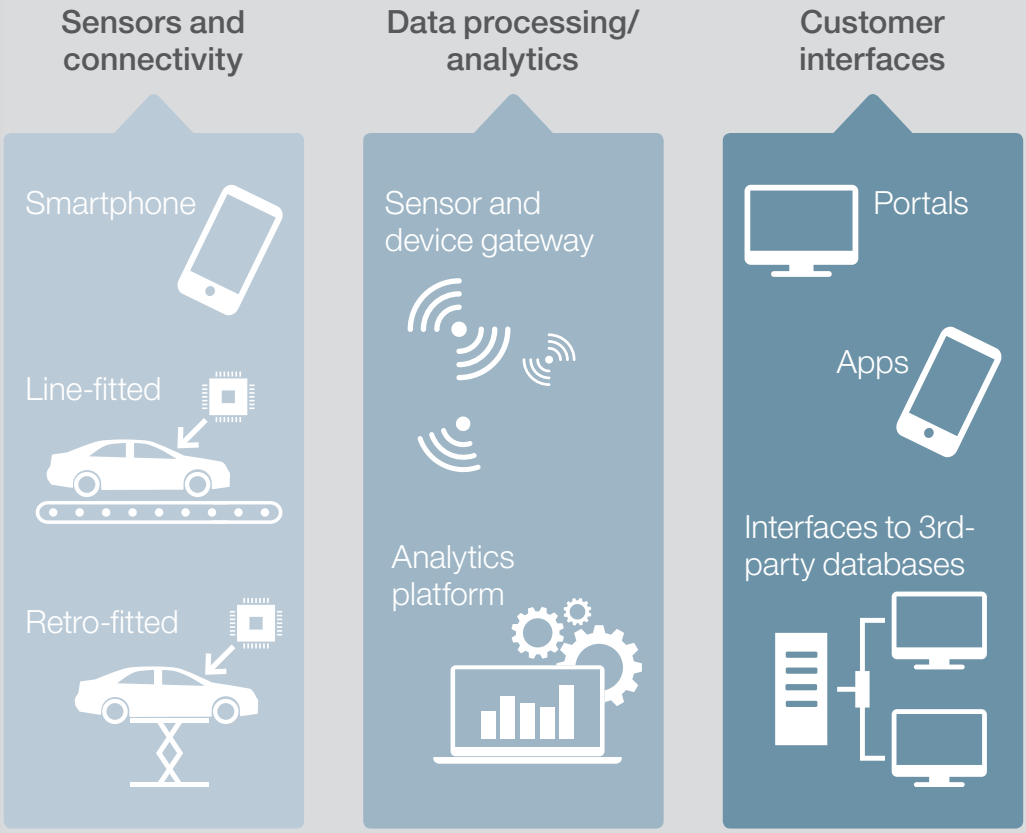
Asset
Identify which assets are used to satisfy particular needs



Delivery model
Define how the value will be captured by and shared between involved players

Monetization
Calculate the total revenue pool and determine how satisfying customer needs can be monetized

The potential service offerings require different building blocks of telematics technology



Businesses planning to enter the market of connected car offerings should follow a 4-step process to assess the potential and fit of the new products and services:

1. **Need.** Understand the customers' needs, e.g., personalized pricing, safety and security, convenience, vehicle maintenance, fleet management.

2. **Asset.** Identify which assets are used to satisfy particular needs, e.g., analytical capabilities, ability to deliver physical services, technological know-how, consumer insights, innovativeness.

3. **Monetization.** Calculate the total revenue pool, e.g., competition for profit pools with competitors vs. division of profit pools among partners, and determine how satisfying customer needs can be monetized through different monetization models such as one-time purchase, subscription, ad supported.

4. **Delivery model.** Define how the value will be captured by and shared between involved players, e.g., stand-alone, with strong partners, as part of an ecosystem consisting of different players, or an ecosystem orchestrator.

Each telematics-based service offering requires a specific combination of technology building blocks. Here is an overview of some basic considerations and rules of thumb in this regard:

- Data processing and analytics are required in every case, but sensors and connectivity as well as the customer interface can be flexibly combined.

- Data processing and analytics require device gateways and analytics platforms.

- As for sensors and connectivity, there are three options:

  — Line fitted, i.e., the device is fully embedded in the vehicle data system and installed by an OEM

  — Retro-fitted, i.e., an external device, which either incorporates its own sensors or connects to a vehicle data bus via interface, and is professionally installed after sale

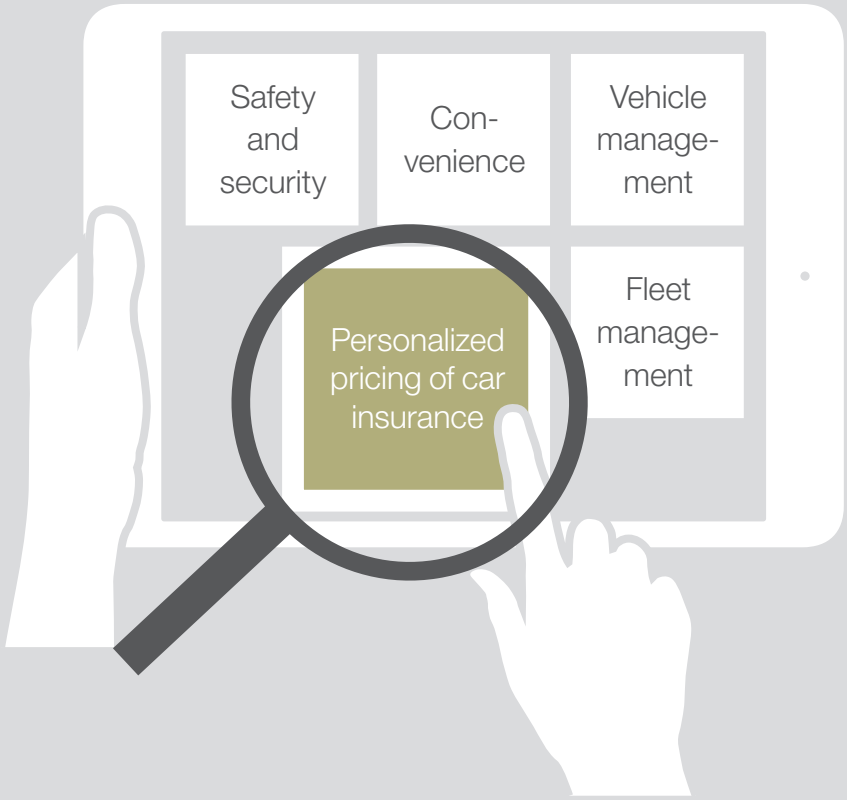
  — Smartphone, i.e., sharing of apps allows the transfer of location data via a smartphone's LTE/4G/GPS system

- The customer interface can be implemented through an app on the smartphone or a computer – or even through interfaces to third-party databases.

Telematics technology serves a broad range of customer needs

Need

Customer needs can be clustered along 5 dimensions



Usage of telematics significantly improves driving behavior and thus facilitates personalized car insurance policy pricing

Selected insights from telematics-based insurance tariffs

Usage of truck telematics has led to:

80%
reduction of fleet incidents

54%
reduction of client crashes

30%
reduction of number of claims

50%
reduction of fleets claim costs

Customer needs that are addressed with telematics-based service offerings can be clustered along five dimensions:

- Safety and security, including stolen vehicle tracking; advanced driver safety coaching; high-risk area warning; individual speed-limit warning
- Convenience, including “find my car” functions; trip and location reporting; concierge services; gamification (incl. basic driver coaching); location-based advertisements
- Vehicle management, including remote diagnostics and condition monitoring; scheduling of repair and maintenance services; predictive maintenance
- Fleet management, including optimization of fleet staffing, loading and routing; advanced driver efficiency coaching; real-time fleet tracking and reporting
- Personalized pricing of vehicle insurance that is based on pay per use (e.g., micro-insurance); driver profiling; policy renewal.

Overview of technology requirements and penetration rates for each sensor type

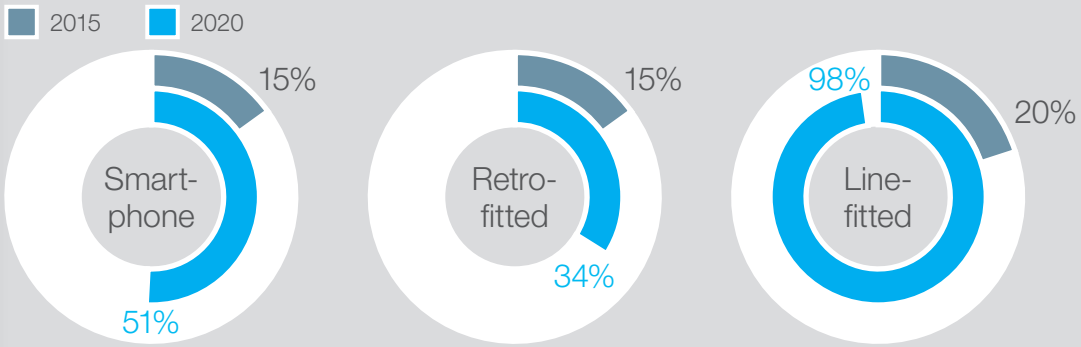
Asset

Each sensor type requires different building blocks of telematics technology

Applicable

	Smart-phone	Retro-fitted					Line-fitted
	Smart-phone	Cigarette lighter	Blackbox	Battery box	Crash recorder	OBD dongle	Installed OBD box
Sensor							
GPS	■	■	■	■	■	■	■
Accelerometer	■	■	■	■	■	■	■
Transmission							
Bluetooth and smartphone		■				■	
SIM	■		■	■			■
Installation							
Self	■	■		■		■	
Professional			■		■		
Line-fitted (OEM)							■

All 3 sensor types' penetration rate of Europe's new car sales are growing stronlgy



Telematics offerings can be designed at very little cost due to scale effects

Typical telematics costs per annum and contract (in EUR)

Transmission fees
depending on choice of technology
~ 5 - 10

Hardware and shipment cost
depending on sensor and sales structure
~ 10 - 25

Platform costs
are mainly fixed costs
~ 10

x7 volume increase

~ 40% cost savings

Telematics unlocks a multitude of automotive revenue streams

Monetization

Overview of the telematics-based applications with the largest revenue-generating potential

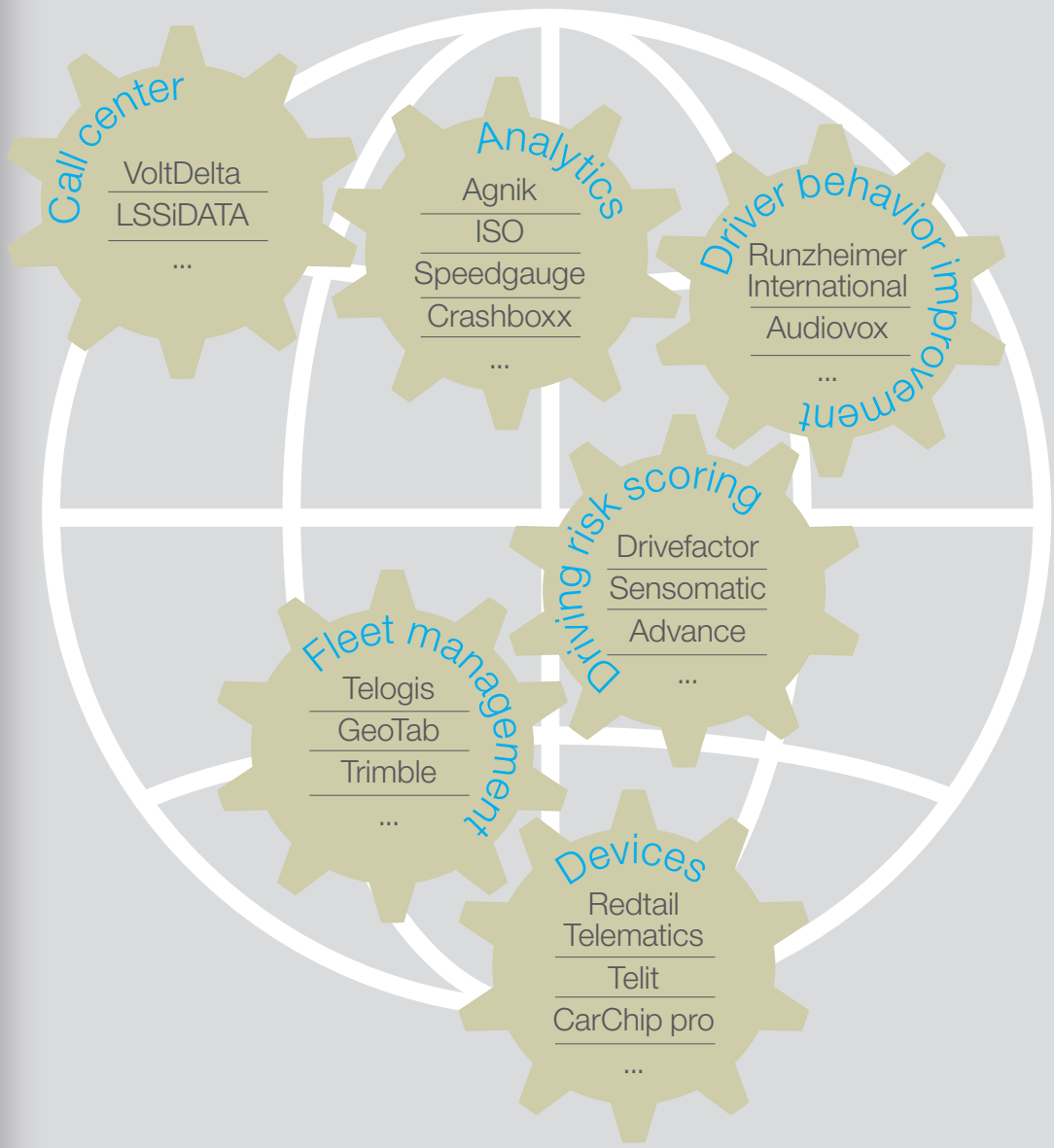
Application	Revenue generating units Thousands 2015 to 2020	Devices and installation EUR billions 2015	Devices and installation EUR billions 2020	Service EUR billions 2015	Service EUR billions 2020
Fleet management	+ ~ 27	0.8	1.4	2.5	6.6
In-vehicle emergency call system	+ ~ 259	0.0	0.3	0.3	1.5
In-vehicle entertainment and Internet access	+ ~ 107	0.4	1.3	1.3	8.8
In-vehicle voice	+ ~ 4	–	–	0.1	0.3
Lease, rental, HP, and share car management	+ ~ 22	0.5	0.8	0.4	1.7
Roadside assistance	+ ~ 188	0.0	0.1	1.5	9.0
Stolen vehicle recovery	+ ~ 299	0.9	2.0	5.1	25.3
Usage-based insurance	+ ~ 128	1.4	4.2	1.2	8.5
Vehicle diagnostics	+ ~ 283	0.1	0.5	2.0	12.5
...					

Source: Machina Research, 2015

Mainhold delivery models allow new competition for attractive segments of the value chain

Delivery model

A broad range of new players compete for the various segments



Exemplary use cases

Volvo and Carlsberg:

Connected fleet for brewery distribution with flexible pay-per-KM service

DPD:

Real-time tracking of parcel through smartphone

John Deere and TimberLink:

Remote monitoring system to drive customer productivity

A new landscape of delivery models is currently developing based on existing and new players. This will result in a new world of business around connected trucks that requires novel partnerships and diverse capabilities around sensor technology, analytics, and service delivery.

First partnerships within these new delivery models are already emerging, for example:

- Volvo and Carlsberg have teamed up to create a connected fleet for their brewery distribution to restaurants and stores with a flexible pay-by-kilometer service for their customers.

- John Deere and TimberLink have partnered to increase their customers' productivity and improve uptime with a remote monitoring system of their vehicles' status to prevent potential maintenance issues.

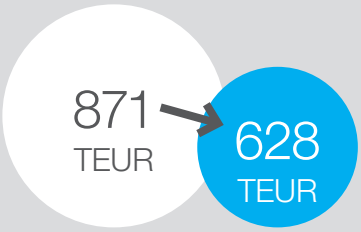
Players within each capability along the new telematics value chain are potentially numerous, and the growth opportunity for OEMs and third-party solution providers who benefit from telematics technology, is promising.

Deep dives on key industry topics

III.C Autonomous driving

Outlook on significant advancement through autonomous truck

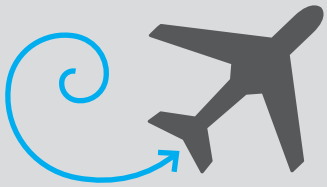
Autonomous driving unlocks vast optimization potential in the truck industry



Up to 28% decrease in average TCO of a 40-ton tractor long-haul truck – from limited ADAS to full AV stage

Up to 5% savings in driving time through route optimizations

Significant capex decrease through approximately 76% fewer crashes



Vast opportunities through spillover to other industries (e.g., airline and insurance industry)

Up to 60% savings in CO_2 through reduced operating ...

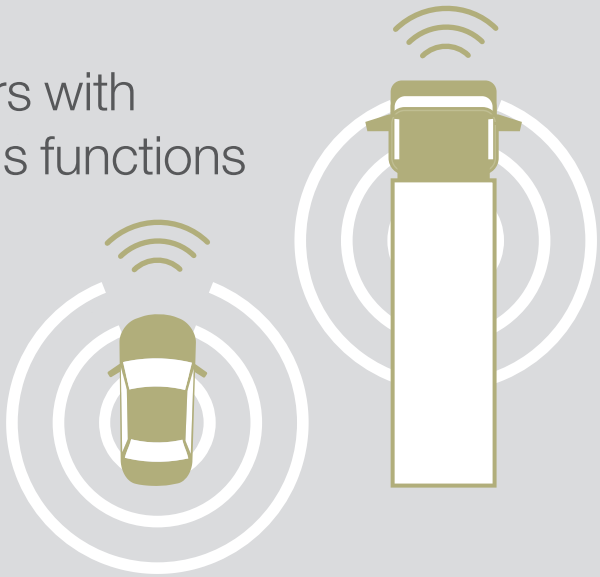
... while labor costs are reduced by up to 90%

Owing to the huge monetary, technological, and societal benefits it generates, automation in the form of self-driving vehicles has the potential to significantly advance the truck and passenger car industries, and even other industries such as insurance, which will be impacted by large spillover effects. Trucks are most likely to be in the driver's seat of the autonomous-driving revolution, while self-driving cars will take more of a back seat, since the long, monotonous highway environment is ideal for trucks while cars mainly have to deal with more complex urban driving situations.

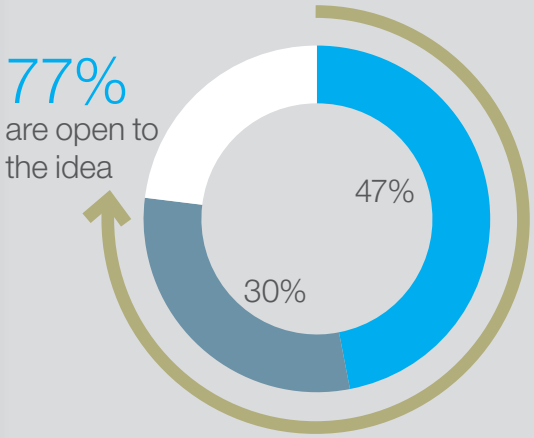
Although the necessary technological developments are basically in place and working (at least for semi-automated vehicles), industry experts anticipate that it will take another ten years before we see fully autonomous trucks readily available for operation on public roads. As this has more to do with policy issues that need to be resolved than with a technology lag, emergence of at-scale use of autonomous trucks will most likely first occur in the US. For among other advantages, the US offers the best-suited legislative system and very open public opinion regarding the technology for autonomously-driving vehicles. What is more, semi-autonomous trucks may even be ready for series production as soon as within the next two to three years.

Customers are open to automation and its pilots

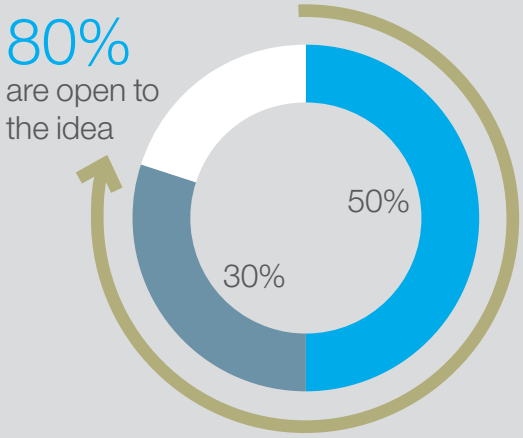
"Should cars with autonomous functions be legal?"



Customers in Germany and the US need to be convinced by pilots to establish trust in the autonomous driving technology



Germany



US

Source: Global McKinsey car survey

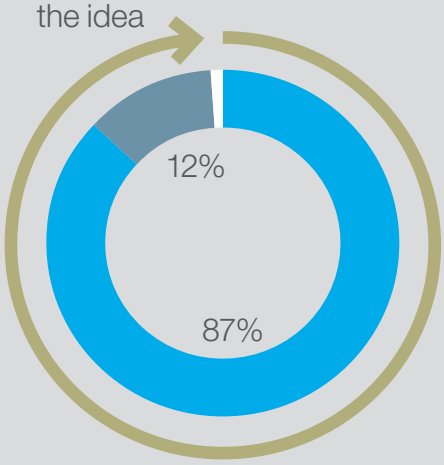
Chinese customers are extremely receptive for autonomous driving

Yes, it should be legal

No, but successful pilots could change my mind

No

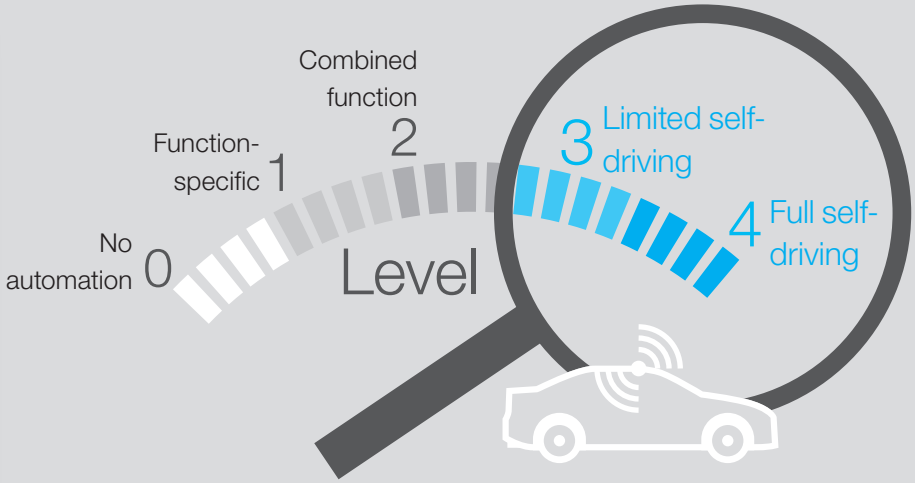
99%
are open to the idea



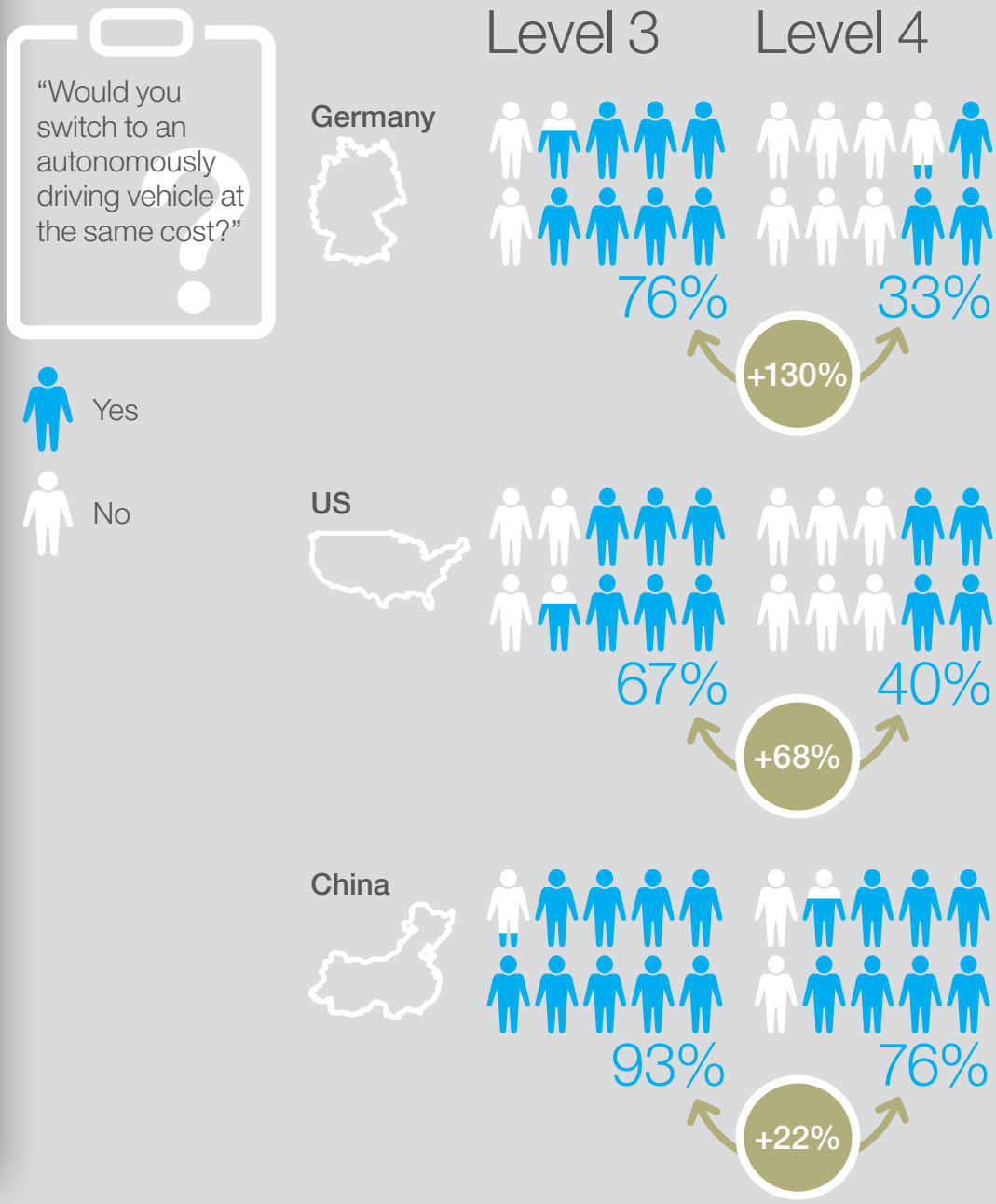
China

Positive public perception of autonomous vehicles can be increased with the option of conventional driving

There are 5 levels of automation



Public perception differs by geographic region and level of automation



The speed of change is dramatic: automotive customers in general continue to request a greater number of Advanced Driver Assistance Systems (ADAS) and autonomy in vehicles ever more quickly, even if there is still some scientism surrounding the technology.

Given that the road to full autonomy is an evolution with increasing levels of ADAS functionalities, it is helpful for orientation purposes to provide an overview of the various automation levels and a timeline of their development based on the National Highway Traffic Safety Administration's (NHTSA) official definition of autonomy in vehicles, which consists of five levels:

- **No-automation (Level 0).** The driver is in complete and sole control of the primary vehicle controls – brakes, steering, throttle, and motive power – at all times.

- **Function-specific automation (Level 1).** Automation at this level involves one or more specific control functions. Examples include electronic stability control or pre-charged brakes, whereas the vehicle automatically assists with braking to enable the driver to regain control of the vehicle or stop faster than possible by acting alone.

- **Combined-function automation (Level 2).** This level involves automation of at least two primary control functions designed to work in unison to relieve the driver of control of those functions. An example of combined functions enabling a Level 2 system is adaptive cruise control in combination with lane centering.

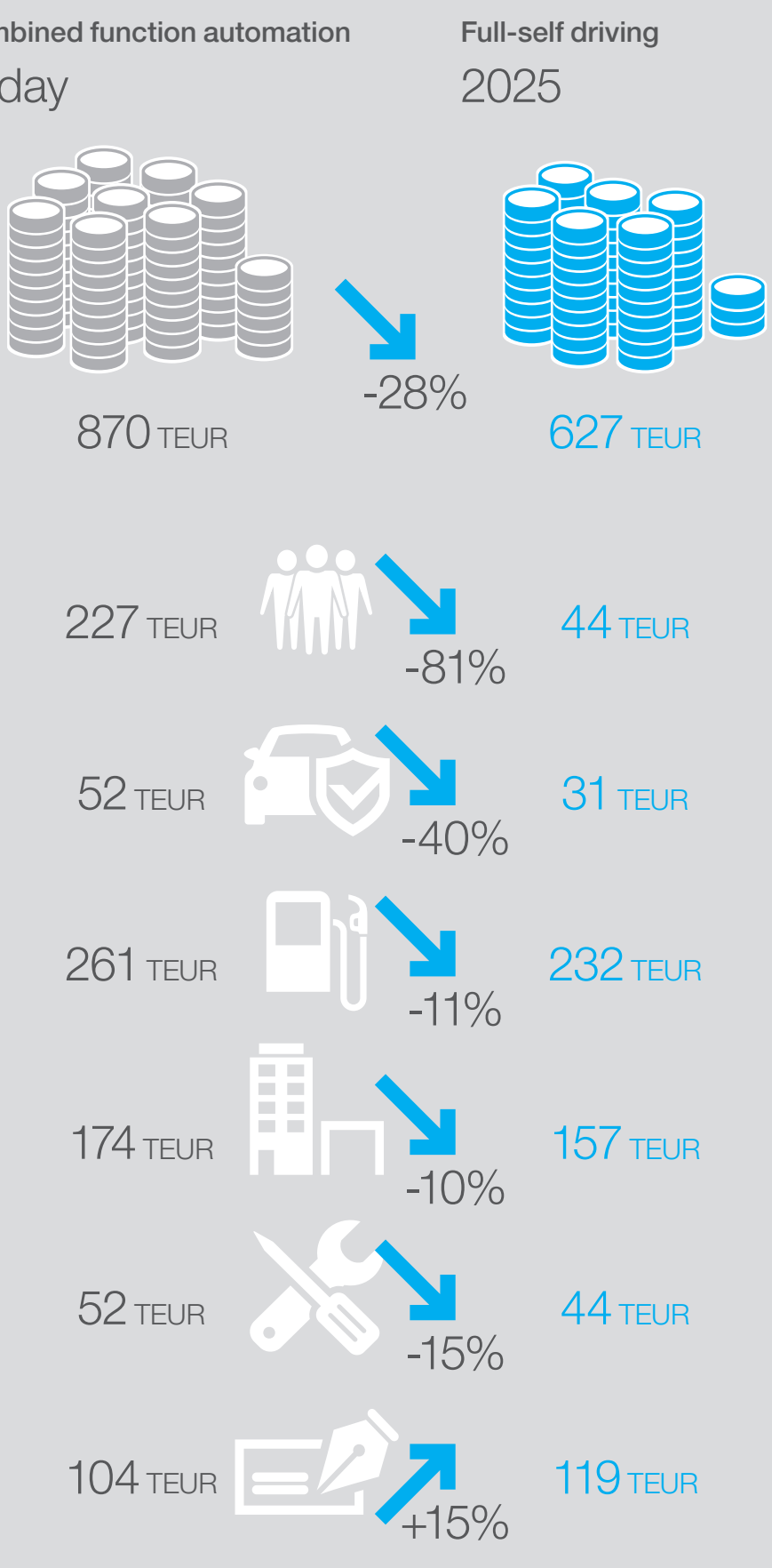
- **Limited self-driving automation (Level 3).** Vehicles at this level of automation enable the driver to cede full control of all safety-critical functions under certain traffic or environmental conditions. And in those conditions, the driver should be able to rely heavily on the vehicle to monitor for changes in the conditions requiring transition back to driver control. The driver is expected to be available for occasional control, but with sufficiently comfortable transition time. The Google car is an example of limited self-driving automation.

- **Full self-driving automation (Level 4).** The vehicle is designed to perform all safety-critical driving functions and monitor roadway conditions for an entire trip. Such a design anticipates that the driver will provide destination or navigation input, but is not expected to be available for control at any time during the trip. This includes both occupied and unoccupied vehicles.

When asked, consumers show a very high willingness to purchase an autonomous vehicle and therefore, it is generally expected that today's scientism view will change as soon as customers are able to actually use the technology and experience its associated convenience. Public perception of autonomously driving vehicles increases significantly when successful pilots are reported and drivers have the opportunity to gain control over the vehicle if necessary.

Impact of autonomous driving on the elements of TCO

~ 28% savings in average TCO (40-ton tractor long-haul truck)



In the truck industry however, customers will not buy into that technology because of convenience. Much more likely, the truck industry will even accelerate the change towards higher level of automation as it enables significant TCO savings (driver's time, fuel, maintenance) and is therefore a "first priority."

More than some 80 percent of the total TCO savings result from cost improvement in the three areas of driver, insurance and taxes, and fuel. Here are some further details on these cost savings:

- **Driver.** As driverless systems suggest, savings here will be derived by reducing driver's time through fully automated vehicles. For lower automation levels, legislation may allow that drivers work longer since they can pause while driving.

- **Insurance and taxes.** Potential reductions of human-caused accidents will lead to lower insurance costs due to less risk that operators have to pay for.

- **Fuel.** Savings can be expected for fuel, due to more predictive gear changes and also due to platooning with little distance between vehicles which leads to more efficient aerodynamic setups.

Even calculated on the basis of current standard combustion engines, the business case is already very convincing. However, the monetary benefits are likely to grow even bigger, when synergies with other future technologies such as electric mobility become reality.

First pilots show revolutionary potential of self-driving trucks for commercial fleets

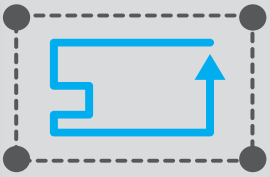
From pilots, standard applications will evolve

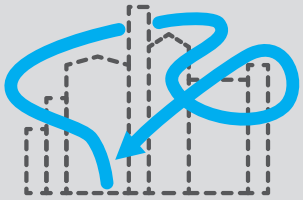
Today → **Medium term ~ 2023 - 2040** → **Long term 2040+**

Autonomous driving already in use in controlled environments, e.g., mining/farming

Autonomous trucks first to enter public roads

Delivery will go beyond roads, e.g., automated planes





There are already successful use cases in adjacent industries

Mining

Autonomous haulage systems (AHS), by Rio Tinto

Farming

Supervised autonomy by John Deere

Full automation by New Holland

Ongoing pilots and research indicate the future of the truck industry

Scania/Volvo:

Tests of platooning systems; trains of vehicles autonomously controlled by one "locomotive"

Daimler:

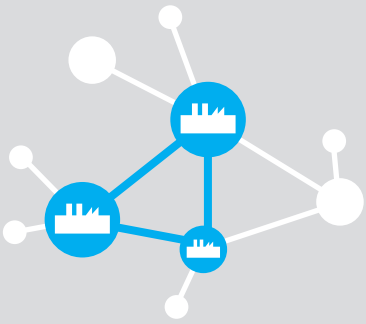
Future Truck 2025 semi-autonomously driving on public roads, no external infrastructure needed

MAN:

First full self-driving protection vehicle that slowly follows mobile construction sites on freeways to save drivers from rear-end collision accidents

We see 6 success factors for truck OEMs regarding self-driving vehicles

Strategic partnership and business model



Strategic partnerships
Engage in ecosystems with defined standards

Business model
Adapt your business model to monetize on additional revenue streams from connecitity features and services

Technology/ information and infrastructure

Technology/information
- Make granular map data available
- Invest in software and tele-matics to deliver interlaces and protocolls for open connectivity

Infrastructure
Ensure coverage of mobile Internet infrastructure

Regulation and public perception

Regulatory changes
Adopt levers to novel technological features, e.g., “hand of the wheel,” speed limits

Public perception/ customer acceptance
- Promote successful pilot testing to relevant audiences
- Secure high safety standards before serial production

What truck OEMs and regulators need to do next

There are several success factors involved in bringing autonomously driving trucks to the market, which can be grouped into company-specific and environmental factors. Concerning company-specific aspects, truck OEMs should take the following steps (and preferably in this order):

- Actively engage in strategic partnerships and industry alliances to achieve the necessary scale and drive creation of industry-wide standards with defined protocols and interfaces. Cooperating with major IT and digital players will likely be necessary in order to gain the required know-how.

- Fulfill and master several technological requirements, such as innovation of sensors, artificial intelligence, and connected technologies that are key in developing autonomous vehicles. Furthermore, granular map data is the basic requirement for establishing autonomous vehicles. Significant R&D expenditure should be supported by early monetization through connectivity features and services (see also Chapter III.A. “New service and business models”).

- Adapt the existing OEM business model based on the new technological features in order to find ways of commercializing on the huge amounts of data generated by the thousands of autonomously driving trucks on public roads. Moreover, the business model should be flexible enough to embrace future technologies such as electric drives.

With regard to the environmental factors, several aspects will influence the timing of the transition to self-driving trucks on public roads. Regulators and relevant authorities should work to:

- Bring about changes to current national regulations and legal environments, especially road regulation and type approval. Regulators are required to grant the OEMs permission to test and further develop their vehicles under real conditions. National laws, such as the US’ Road Traffic Act (RTA), must be changed so that drivers will be allowed to take their hands off the steering wheel while in motion.

- Further improve public perception and consumer acceptance of autonomous vehicles. Consumers already find ADAS features very useful and are willing to give up car control (e.g., one-third of new car buyers would allow their connected car to keep them from exceeding the speed limit). And while people are generally open to autonomous driving, there are significant regional differences where autonomous trucks could face resistance from policymakers as well as the public.

Open questions on the road ahead

The exact pace and magnitude of the shift toward fully autonomous trucks remain uncertain. The answers to several questions will determine what the truck market and the long-haul sector look like 15 years from now:

- Will all OEMs be capable of stemming the technical challenges and standing the often protracted regulatory change processes?

- With thousands of autonomously driving trucks on public highways, the question of how to solve the "problem of the last mile" (e.g., from leaving the highway to the final destination) still remains unsolved and potential solutions need to be discussed.

- And finally, when all these challenges have been overcome, will the advancements lead to increasing sales as transportation volume shifts toward the street?

It appears that with all the advancements that have been achieved, many opportunities exist for truck OEMs and other stakeholders to gain a significant competitive advantage in being able to shape the future of autonomous trucks in the industry and beyond.

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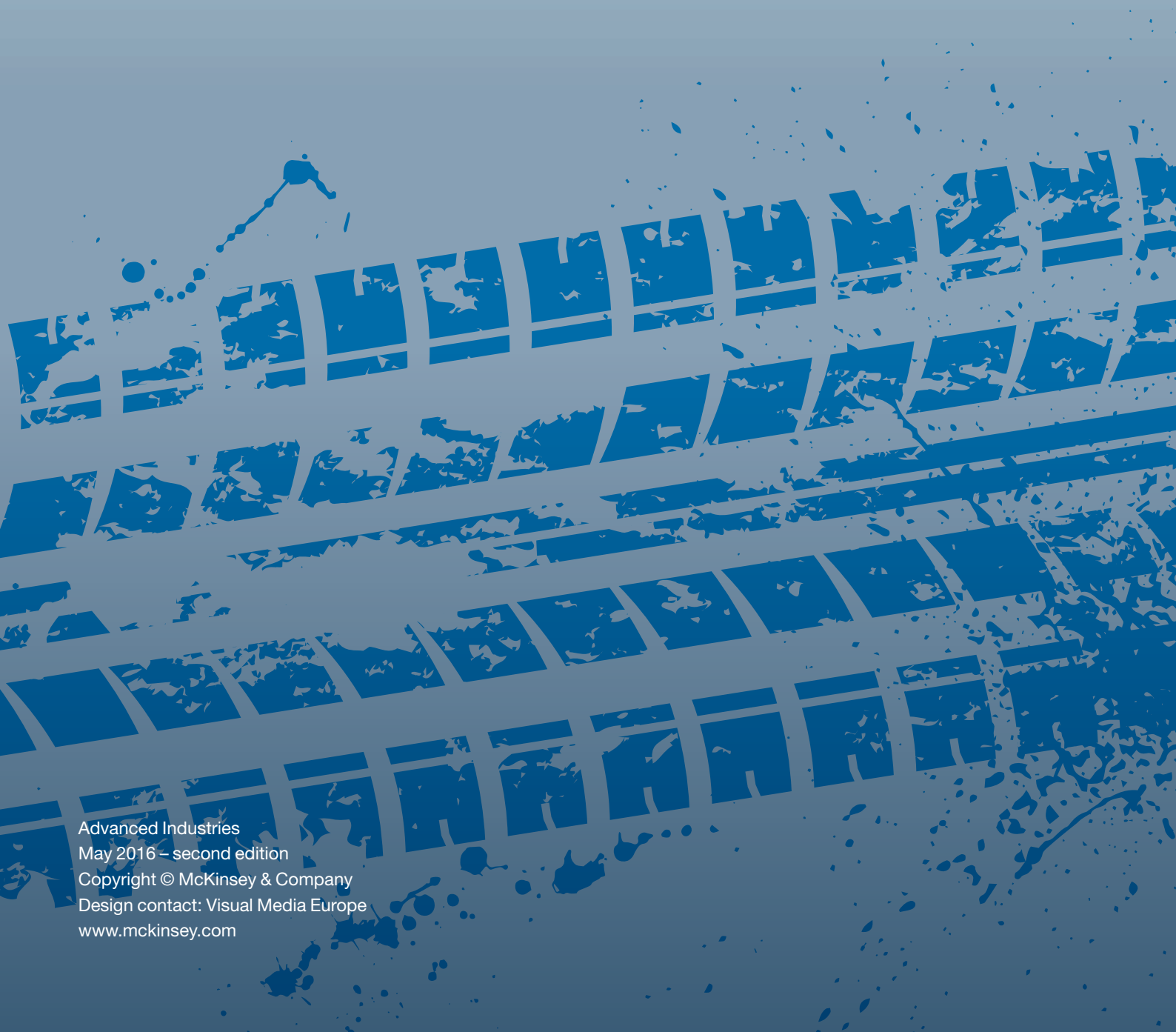

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