Worldwide Trends impacting the Automotive Industry

Global Trends

Environment
Climate Change
CO2 and Fleet Consumption

Economy
Shrinking Resources

Politics
Entry Restrictions

Urbanization
By 2030, over 60% of the world’s population will live in cities

Culture
Sustainable mobility as part of modern lifestyles, social responsibility

Customer
Wishes Value Change

Electric Vehicles
Industry 4.0
Automated Drive
Smart City
Connected Car
Mobility on Demand

Source: 39. Internationales Wiener Motorensymposium 2018
Shares of Individual Economies in the World.
GDP measured in PPP%

Brazil 2017 3%

Global population and World Primary Energy Consumption

- The end of two world wars spurred the greatest boom in human history
- Growth is now waning

Last estimates 9,8 bn
under 1,5 bn Industrialized Countries

Source: US census bureau, Thomlinson, Biraben, Durand, Haub, McEvedy
World Primary Energy Consumption

World Primary Energy Consumption (Million Tons of Oil Equivalent, 1950-2050)

Climate change

Emissions and temperature rise

Cumulative CO2 emissions of the world since 1876

Limit Year 2040

Year 2017

Year 2010

CO2 maximum to +1.5 °C target

Global temperature rise since 1875

Year 1875

Source: IPCC; Global Carbon Project
Foto: Getty/F.A.Z.-Grafik Brocker

2) After 2017: projections
3) Average temperatures between 1850 and 1900
Scenario consideration of CO2 exposure
Paris, Kattowitz

Source: International Energy Agency (IEA), 2015
Atmospheric concentration of CO2 [ppm]

Source: National Oceanic and Atmospheric Administration, USA, 2016
Historical development of drive concepts

- In 1900, the electric motor was the leading car drive, gradually being displaced by the internal combustion engines (ICM).

- 1886: Benz Patent Motor Car Number 1 with ICM

- 1899: The Porsche / Lohner with wheel hub motors is developed and presented in 1900 at the Paris World Fair.

- 1902: First “Hybrid”

- USA / 1900:
  - 40% steam
  - 38% electric
  - 22% gasoline

Worldwide production of electric cars:

- 2012: 168,000 (0.2% of 80 million)
- 2014: 403,000 (0.5% of 86 million)
- 2016: 800,000 (0.85% of 95 million)
- 2018: 2,100,000 (2.2% of 95 million)

2018 China’s global EV share was 56%
Vertical shifts in automotive value creation until 2030

Outsourcing from OEMs to suppliers will continue but slow down; in E-Drive, OEMs will gradually build up own competence and rely for ADAS on suppliers.

2012 (vs. 2002)            2017            2030

<table>
<thead>
<tr>
<th>Chassis</th>
<th>OEMs</th>
<th>Suppliers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drivetrain</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ICE/aux. Systems</td>
<td></td>
<td></td>
</tr>
<tr>
<td>E-Drive (incl. battery)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Body structure</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Exterior</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Interior</td>
<td></td>
<td></td>
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<tr>
<td>E/E¹</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

1. Driven by advancement of ADAS and autonomous driving (AD)
Source: Oliver Wyman value creation model
Platforms & Reversal of Weight Spiral
New Platform Concepts

MQB

“One of the prominent characteristics of the Modular Transverse Matrix is the uniform mounting position of ALL engines. Assembly kit allows for synergies between all vehicle classes”

• 2020 scale: 5.6 million units
• 2020 program count: 130+

Source: IHS December 2013
Global Light Vehicle Production 1950-2026

Sources: ACEA, Environmental Sciences Europe, ICCT, IHS, OICA, Turner, Mason & Company, Wards Communications, IHS March 2019
Top 10 Light-Vehicle Markets - 2025

Light Vehicle Markets (Sales) - [in millions]

<table>
<thead>
<tr>
<th>Region</th>
<th>Sales (in millions)</th>
</tr>
</thead>
<tbody>
<tr>
<td>China</td>
<td>33.1</td>
</tr>
<tr>
<td>NAFTA</td>
<td>20.4</td>
</tr>
<tr>
<td>West Europe</td>
<td>16.0</td>
</tr>
<tr>
<td>Indian</td>
<td>6.7</td>
</tr>
<tr>
<td>East Europe</td>
<td>6.3</td>
</tr>
<tr>
<td>Mercosur</td>
<td>5.6</td>
</tr>
<tr>
<td>Japan</td>
<td>4.7</td>
</tr>
<tr>
<td>ASEAN</td>
<td>4.4</td>
</tr>
<tr>
<td>Middle East</td>
<td>3.6</td>
</tr>
<tr>
<td>Africa</td>
<td>2.3</td>
</tr>
</tbody>
</table>

## Average Light Vehicle Transaction Price
### EU&NAFTA/ China / India / Brasil

<table>
<thead>
<tr>
<th>Country</th>
<th>Average Light Vehicle Transaction Price</th>
<th>GDP per capita 2017 (PPP)</th>
<th>Vehicles per capita/ 1000 inhabitants</th>
</tr>
</thead>
<tbody>
<tr>
<td>EU &amp; NAFTA</td>
<td>33.000 $</td>
<td>37.200 $</td>
<td>USA 788</td>
</tr>
<tr>
<td>China</td>
<td>22.000 $</td>
<td>16.800 $</td>
<td>~ 173</td>
</tr>
<tr>
<td>India</td>
<td>15.000 $</td>
<td>7.000 $</td>
<td>~ 22</td>
</tr>
<tr>
<td>Brazil</td>
<td>22.000 $</td>
<td>15.500 $</td>
<td>~ 341</td>
</tr>
</tbody>
</table>

GDP PPP World = 17000 $ (2017)

**Sources:** CIA Factbook, U.S. Census Bureau, Worldbank, Statista.com, own estimates

- GDP per capita 2017 (PPP)
- Vehicles per capita/ 1000 inhabitants
- USA 788
- EU 500
- ~ 173
- ~ 22
- ~ 341
The automotive revenue pool will grow and diversify [USD billions]

Traditional automotive Revenues 2016
Vehicle Sales dominant

New automotive revenues, 2030
Recurring revenues significantly increasing

Recurring revenues
- Shared mobility penetrates and suburban cities with new car sharing and e-hailing business models\(^1\)
- >USD 100 billion from data connectivity services, incl. apps, navigation, entertainment, remote services, and software upgrades

Aftermarket
- Growth with increased vehicle sales
- Higher annual maintenance spend for shared vehicles
- 20-30% lower maintenance spend on electric powertrains
- Up to 90% lower average crash repair per autonomous vehicle

One-time vehicle sales
- ~2% annual global increase in vehicle sales
- Price premiums paid for electric powertrains and autonomous driving technology features

\(^1\)Does not include traditional taxi and rentals, Source: McKinsey (2016)
Passenger car GHG emissions/fuel consumption [g/km]

- Emission regulations force automotive OEMs to introduce an increasing share of xEVs from 2020 onwards in major regions
- Changes in US regulations likely

**GHG emissions/fuel consumption (CO\textsubscript{2})**

1. CO\textsubscript{2} emissions target\textsuperscript{1)}
2. CAFE\textsuperscript{2)}
3. Additional ZEV regulation CARB
4. Fuel efficiency targets\textsuperscript{3)}
5. CAFC\textsuperscript{4)} (ph.IV)
6. Add. Potential fleet xEV target share

99 % of toxic emissions CO, HC, Nox will have been reduced between 1970 and 2020

\textsuperscript{1)} Weight-based corporate average \textsuperscript{2)} Footprint-based corporate average: converted to NEDC \textsuperscript{3)} Weight-class based corporate average: showing JC08 \textsuperscript{4)} Weight-class based per vehicle and corporate average

Source: Roland Berger (2017)
Energy: total balance of a car

Product Live Cycle Assessment

Well-to-Wheel
- Mining
- Transport
- Processing
- Fuel

Raw Material Extraction

Material | production | Use | Recycle
Transition to Renewable Energy for Mobility

- Coexistence of combustion engine and electric traction
- The aim of both technologies is the use of renewable energies

Source: 39. Internationales Wiener Motorensymposium 2018
CO2 life-cycle emissions: conventional, CNG and electric vehicles

Comparison vehicle Volkswagen Golf (running performance 200,000 km)

- Electric vehicle
- Renewable Energy
- EU
- USA
- CHINA

- Gas (CNG)
- Audi e-Gas
- Biomethane
- Natural gas
- Diesel
- Petrol

Alcohol!!!

CO2-Emissions (g/km)

- vehicle manufacture (Cradle-to-Gate)
- fuel supply (Well-to-Tank)
- utilisation (Tank-to-Wheel)

1) Calculated with wind power 2) Methane from wind power using the example of the Audi e-gas plant Werlte 3) Renewable Energy Directive (EU) 4) Assumption BAT: Erdas from Norway without biogas share 5) WTW balance with 7% or 5% bioethanol according to EN 590 and EN 228 specific CO2 reduction of biofuels amounts to 35% according to EU directive 2009/28 EC

Source: 39. Internationales Wiener Motorensymposium 2018
World leader in battery manufacturing

Capacity in GWh\(^1\)

market shares in %

| 10  | Panasonic |
| 25  | LG Chem   |
| 25  | CATL      |
| 40  | others    |

1: gigawatt hours; 2 forecast. Source: Roland Berger, Bernstein Research, mm-Research; Graphic: MM
Future investments to meet the need for chargers in Billion$

Estimated number of chargers,\(^1\) million

- USA: 11
- China: 19
- EU: 17

Charging time for 400 km:
- 24 h at 3.6 KW up
- 12 min. at 350 KW
- Target under 10 min.

\(^1\)Figures may not sum, because of rounding
Upcoming battery development steps
Lithium-ion battery demand by segment

**EV battery pack price reduction**

- Updated battery pack price projections: New battery technologies lead the cost reductions

- Technological innovation has historically driven declining battery costs, prediction: this will continue, which will keep improving EV economics

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**Powertrain cost comparison for 60kWh/500km range (w/o subsidy)**

- LFP for China, NMC 111 prevalent
- NMC 622+ (<5%) silicon
- NMC 811+ (<10%) silicon
- Solid-state battery
- Future? (Li-Air…)

Note: Analysis is based on a 60kWh BEV, the cost for an ex-battery powertrain part for an EV is estimated at US$2,000
Sources: Bloomberg L.P., SNE Research, and Bernstein estimates and analysis
Main factors influencing the long-term Global technology distribution

Source: 39. Internationales Wiener Motorensymposium 2018
Role of FCEVs in the decarbonized mobility system

Source: 39. Internationales Wiener Motorensymposium 2018
Way towards zero net-impact emissions of Passenger cars and commercial vehicles.

2030 Reduced local emissions

-2040 Zero local emissions in cities

2050+ Zero net-impact emissions

Tank-to-wheel CO₂-emissions reduction

Reduction of real-world emissions of passenger- and commercial-vehicle fleets

Emission-free cities¹

Zero local emissions in urban areas, use-case-based application of combustion motors in suburban and rural areas

Well-to-wheel CO₂-emissions reduction²

Zero local and zero well-to-wheel emissions through renewable energies for electricity/hydrogen and alternative fuels²

¹Battery electric vehicle, plug-in-hybrid electric vehicle, and fuel-cell electric vehicle as predominant powertrain technologies for cities and urban areas.
²For example, synthetic fuels and biofuels.

Source: McKinsey Center for Future Mobility analysis
Architecture complexity: consequence of digitalization

Traffic deaths worldwide
1.35 million / a
Asia 770
Europe 75
Central / North America 66

Lines of code

2M Hubble Space Telescope
5M Mars Curiosity Rover
12M Smartphone OS
25M F-35 Fighter Jet

Luxury car software 100M

Cars are more and more developing towards software products, containing already more lines of code than Windows 8 and Mac OS X ...

Source: Roland Berger, CarsGuide, High volume global automotive platform
The 2050 vision includes innovations across powertrain portfolio, business models, technologies, and mobility-type-specific solutions.

**Selected examples, by dimension**

<table>
<thead>
<tr>
<th>Sustainable mobility portfolio</th>
<th>Business-model innovation</th>
<th>New technology innovation</th>
<th>Targeted solutions for each mobility scenario</th>
</tr>
</thead>
<tbody>
<tr>
<td>We consider multiple powertrain solutions, energy supply chains, and ecosystems.</td>
<td>We create a framework for offering innovative business models that benefit mobility consumers.</td>
<td>We build an ecosystem for leading development and rollout of future high-tech solutions.</td>
<td>We promote development of different mobility and transport solutions and ecosystems for individual requirements.</td>
</tr>
<tr>
<td>Electric</td>
<td>Data driven</td>
<td>Connected cars</td>
<td>Seamless and multimodal</td>
</tr>
<tr>
<td>Advanced ICE(^1)</td>
<td>Pay per use</td>
<td>Autonomous driving</td>
<td>Private autonomy</td>
</tr>
<tr>
<td>Hydrogen</td>
<td>Carsharing</td>
<td>Truck platooning</td>
<td>Last-mile delivery</td>
</tr>
<tr>
<td>LNG/CNG(^2)</td>
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<td></td>
</tr>
</tbody>
</table>

\(^1\)Internal-combustion engine.
\(^2\)Liquefied natural gas/compressed natural gas.

Source: McKinsey Center for Future Mobility analysis.
The 2050 vision for the European mobility Industry.

Benefits for the mobility customer of 2050

**People**
- Zero fatalities and accidents
- Individual mobility accessible to up to ~90% of population
- Shift of 50% of commuting time to value-add time
- Mobility companies as best places to work for

**Planet**
- Zero emissions in cities
- Zero net well-to-wheel emissions
- 20–30% of traffic space transferred into livable spaces
- Optimized traffic flow and 20% less congestion

**Profit**
- Mobility costs might decrease down to ~€0.10 per km
- Transportation costs could decrease 40% per km due to autonomous vehicles
- Attractive job opportunities with above-average salaries

*Source: McKinsey Center for Future Mobility analysis*
## Global Growth of Asian OEMs

<table>
<thead>
<tr>
<th>Year</th>
<th>Japan</th>
<th>South Korea</th>
<th>China</th>
</tr>
</thead>
<tbody>
<tr>
<td>1970's</td>
<td>Toyota Crown</td>
<td>Hyundai Excel</td>
<td>Chery Deer Mid/East</td>
</tr>
<tr>
<td>1980's</td>
<td>Toyota Corolla</td>
<td>Hyundai Accent</td>
<td>Great Wall Haval H6</td>
</tr>
<tr>
<td>1990's</td>
<td>Honda Accord</td>
<td>Hyundai Tucson</td>
<td>Volvo S60</td>
</tr>
<tr>
<td>2000's</td>
<td>Lexus RX</td>
<td>Kia Cee'd</td>
<td></td>
</tr>
<tr>
<td>2010's</td>
<td>Toyota Prius</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2020's</td>
<td>Toyota Corolla</td>
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</tr>
</tbody>
</table>
GDP per capita based on PPP?
What does that mean for you?

- Brasil fits perfectly into the environmental trends that will gain even more priority in the next decades (from alcohol as fuel via natural fibers to the general CO2 footprint). Brasil could be a world leader in „green technology“ which will grow and flourish and will be a good business. Learn to export it!

- Brasil will be a follower in electrification and automated driving. Just copy.

- Brasil will remain an emerging country that does not allow to successfully copy products developed for the „rich world“ for the local mainstream market.

- There are suppliers in Brasil that earn really good money since the Brasilians are – under good leadership – adopting change faster than most of the world.

- Cooperations will be crucial for the future success of the automotive industry! Be a frontrunner in bundling forces with frienemies. The Brasilian cultural openness and moderate pride are key ingredients for success. Demonstrate to your mother companies that it works!!

- Perceived corruption in Brasil is bigger than real corruption. Just continue to act! Off course there are many duties remaining for the „political Brasil“ from pension- to tax- to education reforms, but who is perfect in our world.