Mobility of the Future

What is next for the automotive industry?

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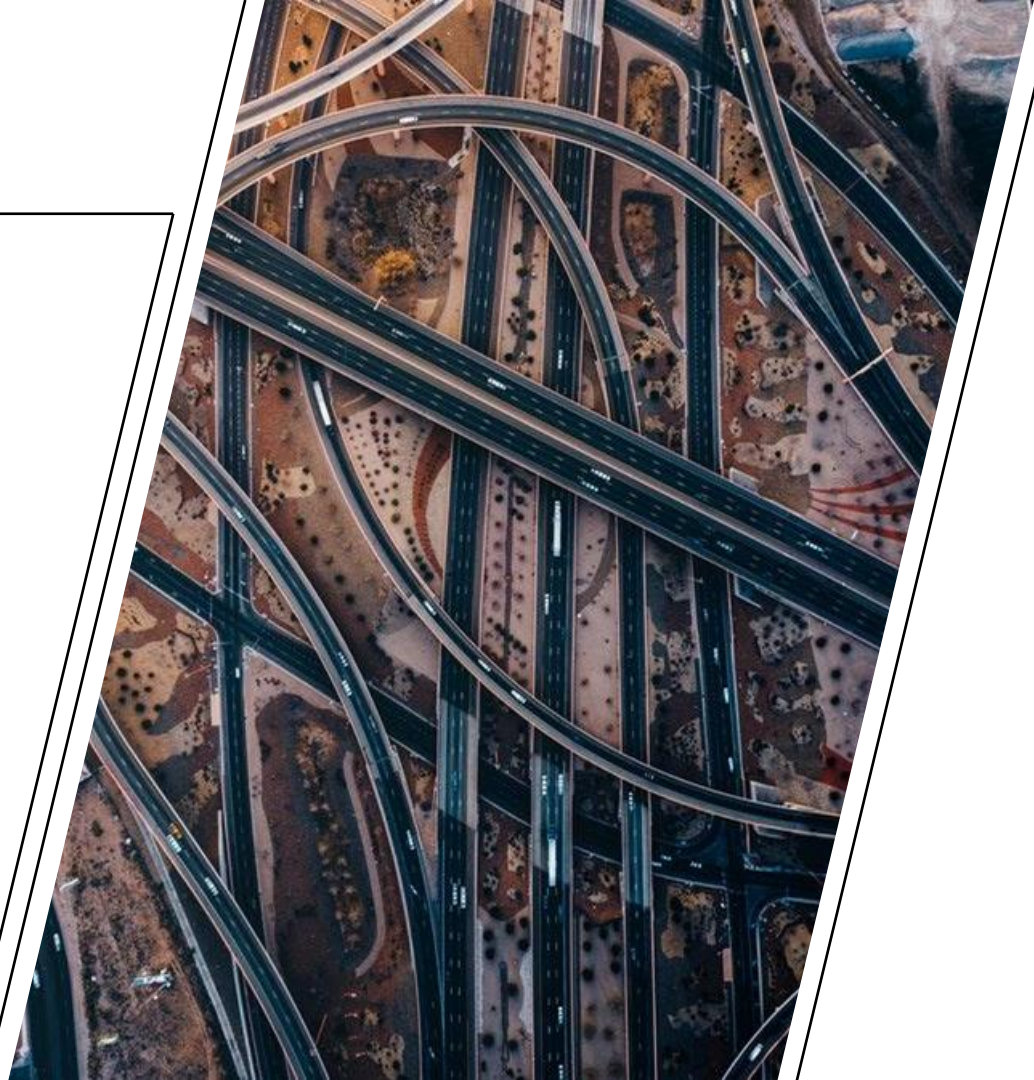
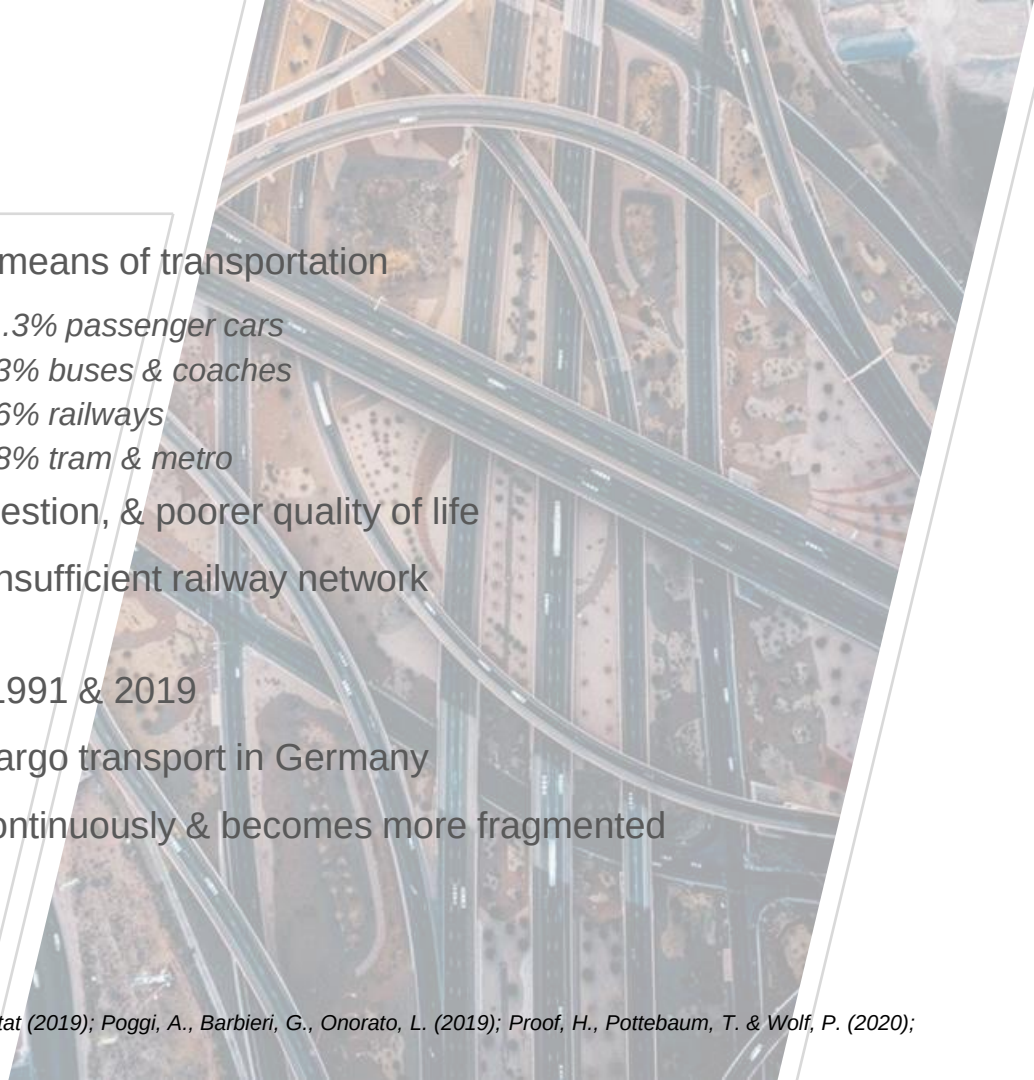


Status Quo I

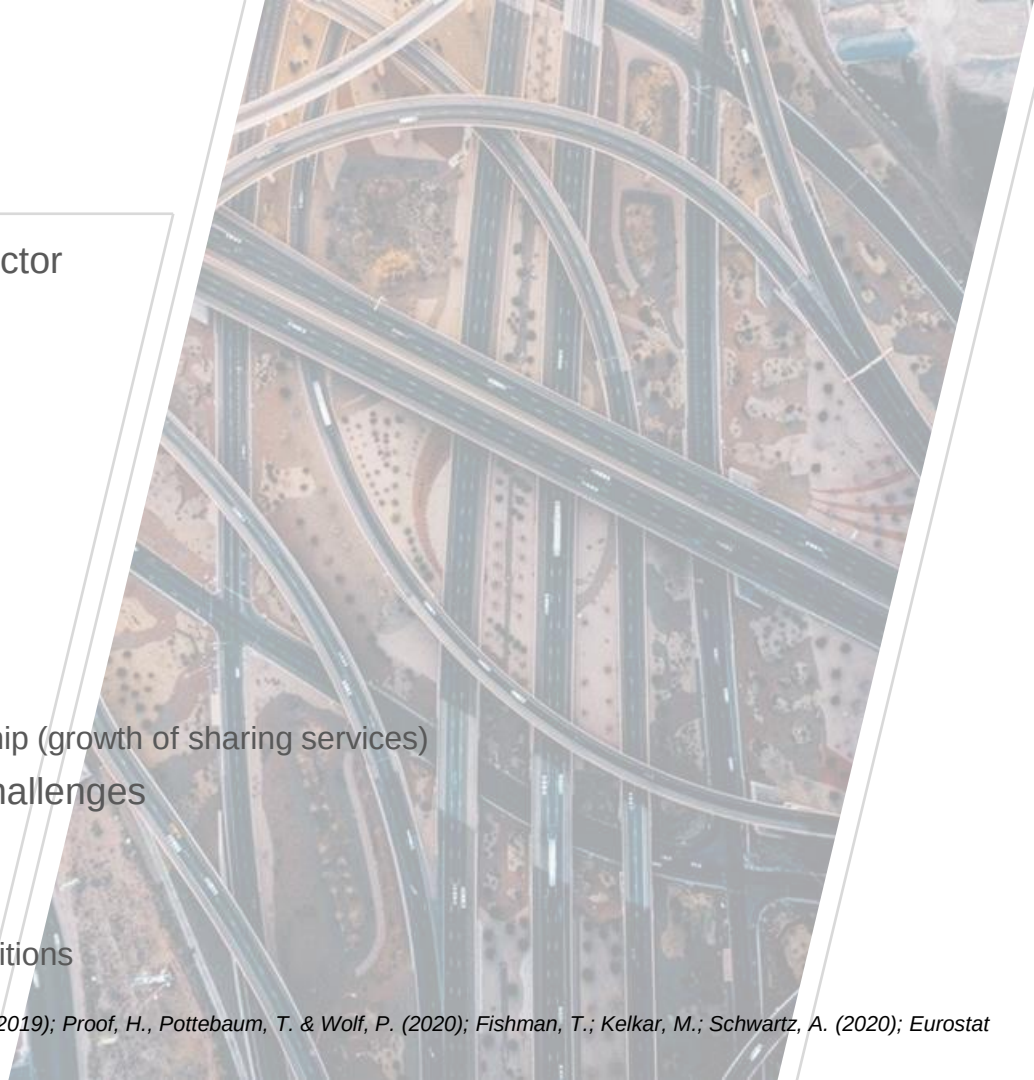
- In Western countries, cars are the primary means of transportation
  - Modal split EU (passengers, 2016): *81.3% passenger cars*
    9.3% buses & coaches
    7.6% railways
    1.8% tram & metro
- Leads to significant economic losses, congestion, & poorer quality of life
- Focus on cars & roads lead to obsolete & insufficient railway network
  → Reinforces people's preference for private cars
- Air transportation grew by 218% between 1991 & 2019
- Commercial vehicles constitute 72.5% of cargo transport in Germany
- International goods transportation grows continuously & becomes more fragmented
  → Individual deliveries from online purchases



Sources: ADAC (2020); BMVI (2021b); Fishman, T.; Kelkar, M.; Schwartz, A. (2020); Eurostat (2019); Poggi, A., Barbieri, G., Onorato, L. (2019); Proof, H., Pottebaum, T. & Wolf, P. (2020); Statista (2021a); UBA (2021)

Status Quo II

- Primary challenges in the transportation sector
  - First- & last-mile transit
  - Climate goals
  - Capacity & traffic optimisation
  - Fragmentation of national systems
  - Protection against cyber threats
- Paradigm shifts disadvantaging cars
  - Environmental consciousness
  - Urbanisation
  - Usership & experiences instead of ownership (growth of sharing services)
- Electric mobility is growing but still faces challenges
  - Insufficient infrastructure
  - Expensive
  - Intransparent information on charging conditions



Sources: ADAC (2020); BMVI (2021b); Castrol (2020); Poggi, A., Barbieri, G., Onorato, L. (2019); Proof, H., Pottebaum, T. & Wolf, P. (2020); Fishman, T.; Kelkar, M.; Schwartz, A. (2020); Eurostat (2019); UBA (2021)

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Propulsion and Infrastructure I

Internal Combustion

- Diesel or Otto engine, very common in many different types of vehicles
- Current issues: emission of CO_2, not environmentally friendly
- Promising: Conversion to alternative fuels possible (e.g. “biodiesel”, biogas or hydrogen)

Hydrogen

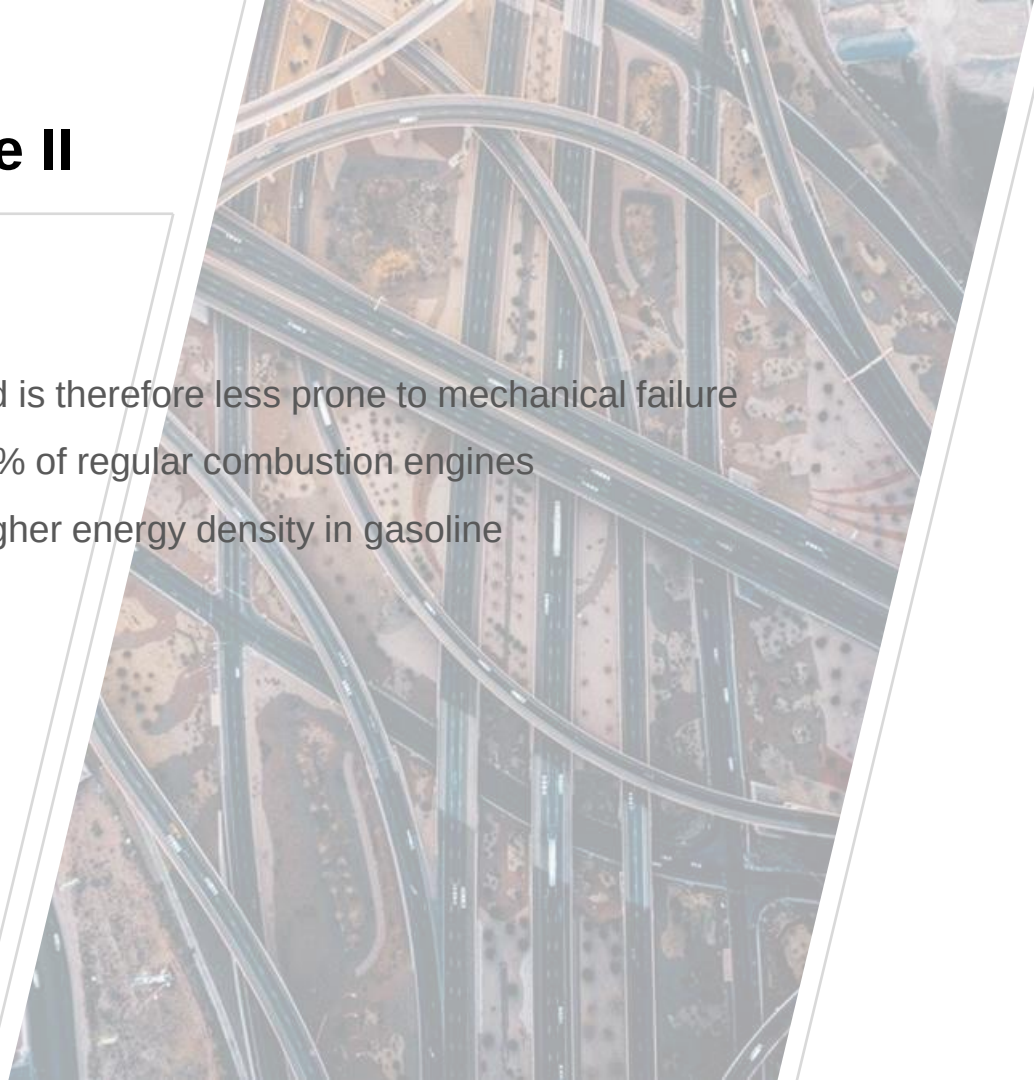
- Technologies: Hydrogen fuel cell & hydrogen combustion engine
- Especially promising for large, heavily used vehicles
- Current issues: Hydrogen production expensive & often not emission free, hydrogen storage complex & dangerous, lacking infrastructure of hydrogen fuelling stations

Sources: Basshuysen (2016); bdew (2021); Green Motors (n.s.); Quaschning (2021)

Propulsion and Infrastructure II

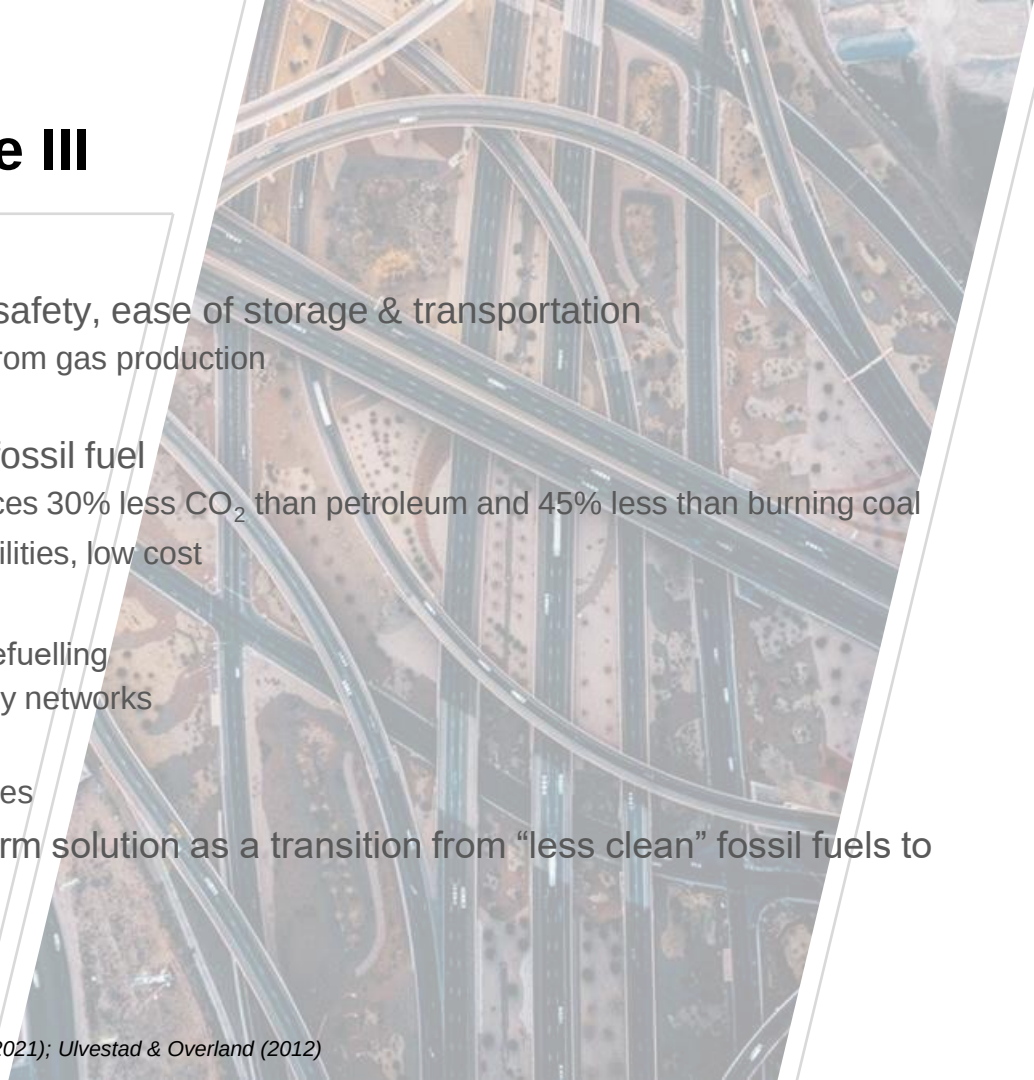
Electric motors:

- Uses electricity to power the vehicle
- Has less parts than combustion engine and is therefore less prone to mechanical failure
- 90% energy efficiency, compared to 35-40% of regular combustion engines
- Currently this advantage is offset by the higher energy density in gasoline
- Future battery technology may catch up



Source: Drive – Volkswagen Group Forum (2021)

Propulsion and Infrastructure III



Liquefied Natural Gas (LNG)

- Natural gas cooled down to liquid form for safety, ease of storage & transportation
  - Increased accessibility for areas far away from gas production
    → Historically localised
- Considered environmentally least harmful fossil fuel
  - For equivalent amount of heat, LNG produces 30% less CO_2 than petroleum and 45% less than burning coal
  - High energy density, quick refuelling capabilities, low cost
- Relatively novel technology
  → Lack of infrastructure for storage, transport & refuelling
  - Refuelling stations dependent on gas supply networks
  - LNG prices relatively unstable
    → unlikely to dominate TCO-driven industries
- However, serious contender for medium-term solution as a transition from “less clean” fossil fuels to more sustainable solutions

Sources: Jentzsch, Janda, Xu, Wiedenhoff & Girisch (2019); Maxwell & Zhu (2011); Shell (2021); Ulvestad & Overland (2012)

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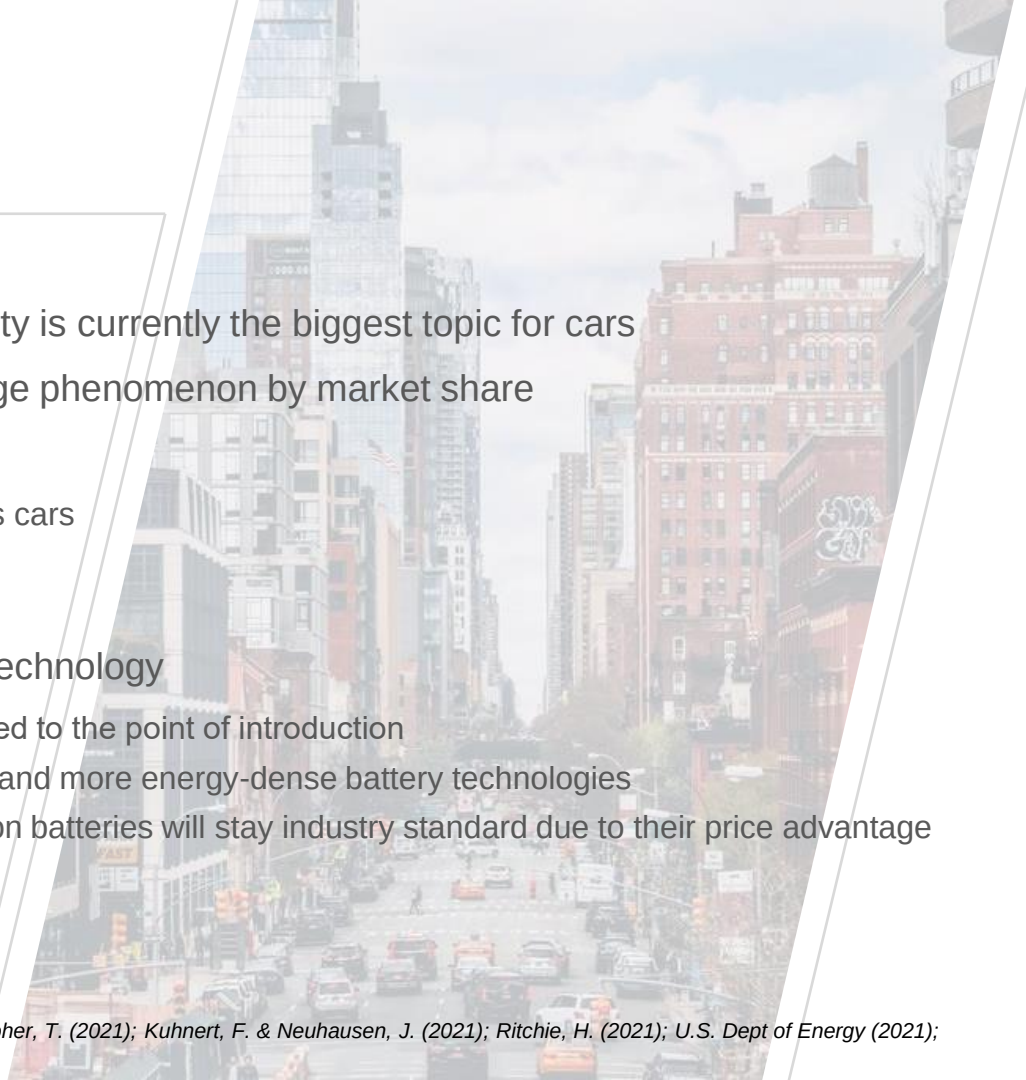
Street: Electric Vehicles I

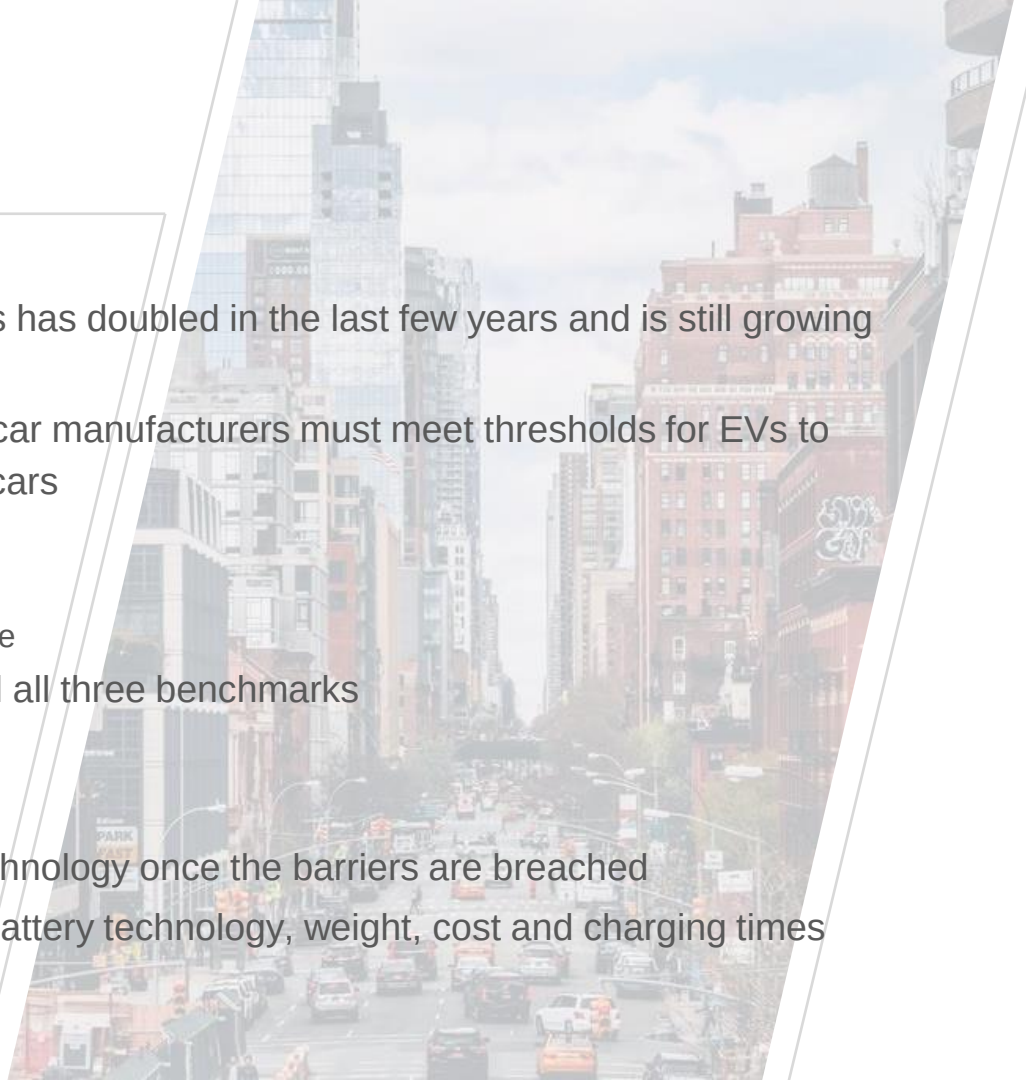


Technology

- Besides autonomous driving, electric mobility is currently the biggest topic for cars
- Electric mobility is a big trend but still a fringe phenomenon by market share
- The technology has multiple upsides
  - More efficient, less operating costs than gas cars
  - Less prone to mechanical failure
  - No local air & noise pollution
- One of the most central aspects is battery technology
  - Today’s batteries are 97% cheaper compared to the point of introduction
  - Ongoing research for more capable, lighter and more energy-dense battery technologies
  - For the foreseeable future, current lithium-ion batteries will stay industry standard due to their price advantage

Sources: Bhatt, A., Withers, R., & Wang, G. (n.d.); BMU (2021); Castelvecchi, D. (2021); Kroher, T. (2021); Kuhnert, F. & Neuhausen, J. (2021); Ritchie, H. (2021); U.S. Dept of Energy (2021); Wietschel, M., Kühnbach, M., & Rüdiger, D. (2019)

Street: Electric Vehicles II



Models

- The number of available electric car models has doubled in the last few years and is still growing rapidly
- However, adoption of electric cars is slow: car manufacturers must meet thresholds for EVs to become viable competition for regular gas cars
  - Range: 469km
  - Price: $30,000
  - Charging Speed: 31 Minutes for a full charge
- Currently, no available electric car can fulfill all three benchmarks

Outlook

- EVs will most likely become a dominant technology once the barriers are breached
- This heavily depends on developments in battery technology, weight, cost and charging times

Sources: Castrol (2020); Transport & Environment (2019)

Street: Autonomous Driving I

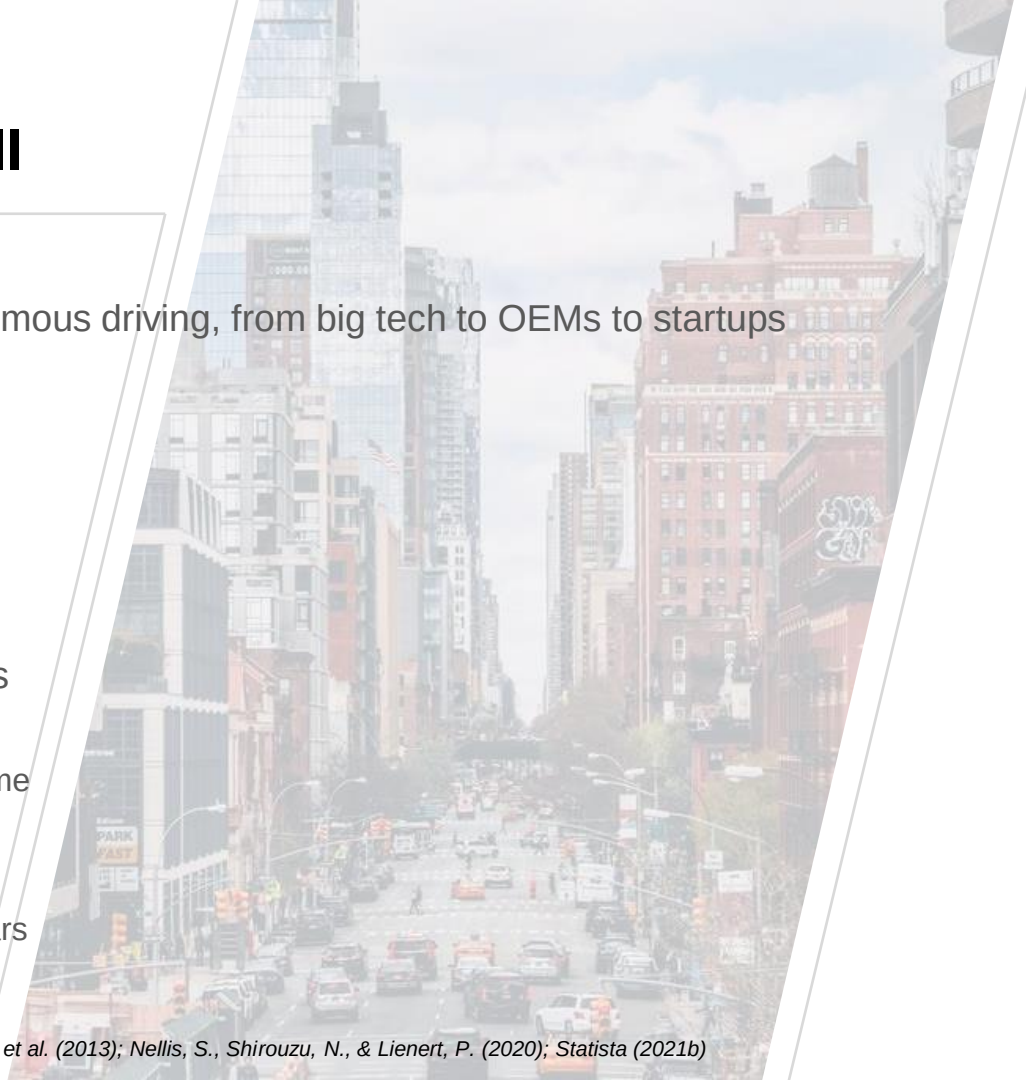
Status Quo

- Autonomous Driving can be measured along a six level scale
  - Level 0: Momentary assistance (e.g. warnings)
  - Level 1: Lane or acceleration/brake assistance
  - Level 2: Lane and acceleration/brake assistance
  - Level 3: Self-driving in limited conditions (e.g. autonomously navigating a traffic jam)
  - Level 4: Local autonomous driving in geofenced areas
  - Level 5: Fully autonomous driving under all conditions

- Modern driving assistants reach level 2
- In some urban areas level 4 autonomy is tested
- Level 5 autonomy is expected to be market ready by 2030 the earliest

Sources: California Department of Motor Vehicles (2021); Dungs, J. et al. (2016); Gessner, D. (2020); Krafcik, J. (2020)

Street: Autonomous Driving II



Technology

- Many companies currently research autonomous driving, from big tech to OEMs to startups
  - Google: Waymo
  - Apple
  - Zoox (acquired by Amazon in 2020)
  - Ford & VW: Argo.AI
  - General Motors: Cruise

- Autonomous cars have multiple advantages
  - Increased traffic safety
  - Transform commutes into work or leisure time
  - Reduce congestion
  - Reduce need for parking space
  - Potential to reduce the need for personal cars

Sources: Eno (2013); Etherington, D. (2020); Geistefeldt, J., & Lohoff, J. (2011); Manyika, J. et al. (2013); Nellis, S., Shirouzu, N., & Lienert, P. (2020); Statista (2021b)

Street: Autonomous Driving III

Challenges

- In the past, autonomous driving was projected to reach the mass market by 2020
  → This has not come true

- Current issues
  - Higher complexity than anticipated
  - Consumer scepticism
  - Ethical considerations: Who is responsible in case of unavoidable accidents?
  - Legal considerations: In most regions autonomous driving is not yet permitted

Sources: Adams, E. (2020); Edmonds, E. (2021); Laing, K. (2021); Statista (2021c); Warren, T. (2016)

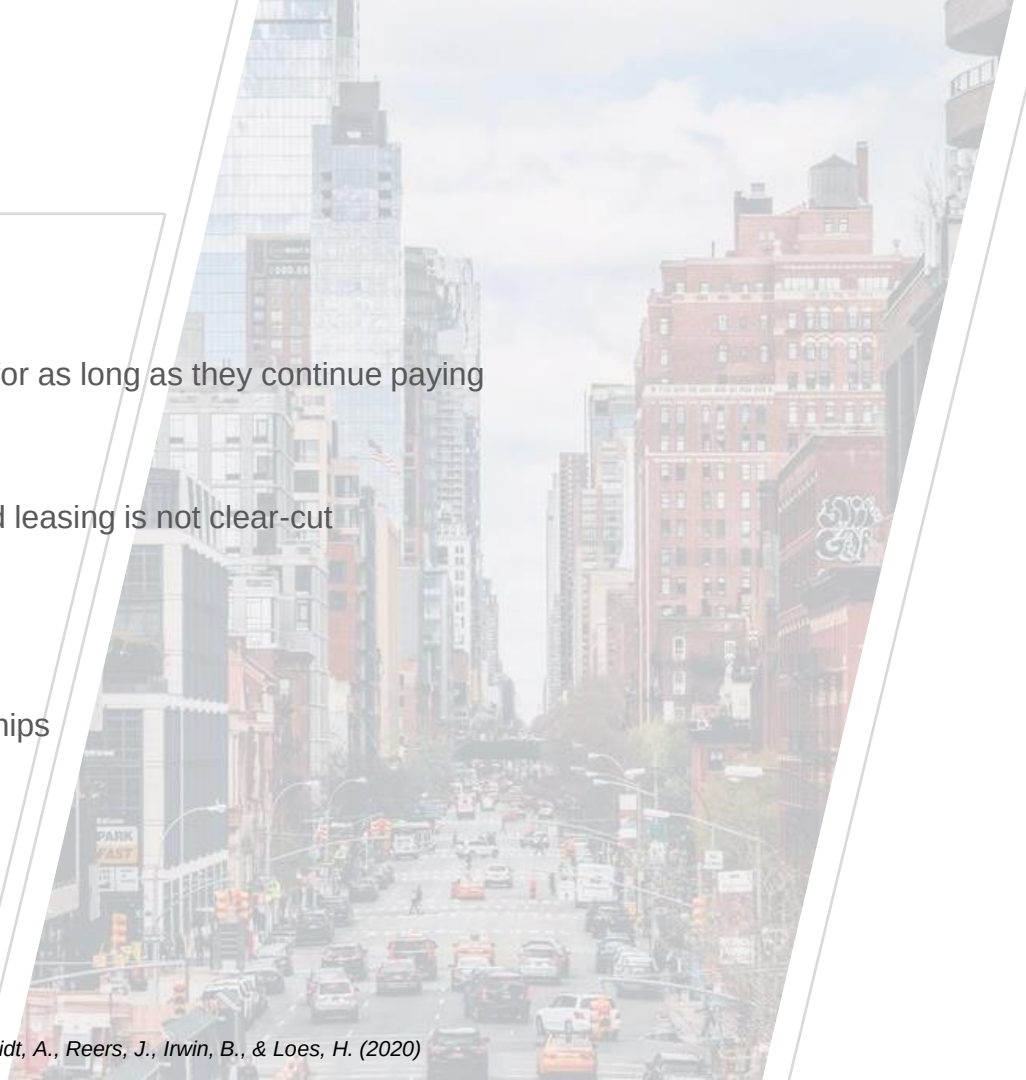
Street: Business Models I

Overview

- Most business models revolve around mobility services
- These can be divided into groups, depending on the user's degree of ownership (as opposed to just using a service)
  i. Owning a car
  ii. New ownership models: almost complete ownership/control
  iii. Vehicle on demand: temporary ownership/control
  iv. Mobility on demand: no ownership/control, focus on service
  v. Using public transport

Sources: Schmidt, A., Reers, J., Irwin, B., & Loes, H. (2020)

Street: Business Models II



ii. New Ownership Models

- Subscriptions to cars
  - Customer pays a monthly fee to use a car, for as long as they continue paying
  - Insurance and repair are often covered
  - Subscription models are flexible
    → Differentiation between subscriptions and leasing is not clear-cut
- Advantages:
  - Flexibility
  - Gateway into car ownership
  - OEMs can reduce their fleet size in dealerships
- Disadvantages:
  - Relatively high price in the long run

Sources: Pander, J. (2019); Schellong, D., Sadek, P., Lang, N., & Mattson, M. (2021); Schmidt, A., Reers, J., Irwin, B., & Loes, H. (2020)

Street: Business Models III

iii. Vehicle On Demand

- Service
- User gets access to a full vehicle in exchange for money
  - Car sharing
  - Bike sharing
  - Electric scooters
- Most prevalent in urban areas
  → Minimum population density needed for the service to work properly

Sources: Bert, J. et al. (2016); BMVI (2019a); BMVI (2019b); Liao, F. et al. (2018); Stolle, W. O. et al. (2019)

Street: Business Models IV

iii. Vehicle On Demand

- Advantages:
  - A reliable network can reduce the need for personal cars
  - For some car owners in cities, car sharing is already cheaper than car ownership
  - Smaller vehicles like scooters have the potential to replace <10% of all car trips in Germany, making traffic less congested and polluting

- Challenges:
  - Most people use car sharing alongside owning a car
  - Currently car sharing is mostly used for convenience
    → Competing with public transport rather than car ownership
  - The market share is very low (<10% across all households)
  - The potential of these sharing models is yet to be seen

Sources: Bert, J. et al. (2016); BMVI (2019a); BMVI (2019b); Liao, F. et al. (2018); Stolle, W. O. et al. (2019)

Street: Business Models V

iv. Mobility On Demand

- Service including taxi and ride hailing services
- Users are driven to their destination instead of driving themselves
- Major growth driver in the mobility business
- Most prevalent in urban and suburban areas
- Advantages:
  - Convenient
- Disadvantages
  - Inefficient
  - In the United States, ride hailing contributes significantly to congestion in urban areas
  - Causes empty trips on public street

Sources: Heineke, K., Kloss, B., Möller, T., & Wiemuth, C. (2021); Henao, A., & Marshall, W. E. (2019); Schaller Consulting (2018); Schmidt, A., Reers, J., Irwin, B., & Loes, H. (2020)

Street: Business Models VI

iv. Mobility On Demand (continued)

- Outlook:
  - Ride hailing & car sharing services are important developments
  - But heir success in changing mobility depends on car ownership
    → If consumers keep owning cars, their effect will be smaller than anticipated

Sources: Heineke, K., Kloss, B., Möller, T., & Wiemuth, C. (2021); Henao, A., & Marshall, W. E. (2019); Schaller Consulting (2018); Schmidt, A., Reers, J., Irwin, B., & Loes, H. (2020)

Street: Local Public Transport (LPT) I

Consumer Perspective:

- Consumers‘ perception on LTP depends on external (nature) & internal (nurture) factors
- They can have positive and negative impacts:

	Positive	Negative
External (Nature)	• Densely populated areas • Speed limits • Increasing gas prices	• High income • Car ownership
Internal (Nurture)	• Reducing / eliminating fares • Route network • Low travel time • Low out-of-vehicle time • Punctuality • Comfort	

Sources: Paulley et al. (2006); Taylor, et al. (2009); Webster & Bly (1982)

Street: Local Public Transport (LPT) II

Technologies:

- Alternative Powertrains: Extensive research, especially on electric battery range (currently ~300km)
- Platooning: Connecting multiple vehicles via software to save costs & gain flexibility
- Autonomous driving: Test runs for partially- & fully autonomous buses & shuttles
  → Addressing first- & last-mile problem

Opportunities:

- Pro-environmental attitudes & political incentives

Threats:

- Cars as third places in the long-run
- Little flexibility & independence

Outlook:

- An increase in local public transportation usage is likely to occur when providers improve nurture factors and public authorities alter nature factors by disincentivizing urban car usage

Sources: ADAC (2020); Bloomberg, N. E. F. (2021); KIT (2021); Nordlund & Garvill (2003); Proterra (2021); Siemens (2021); Yutong (2021)

Street: Intercity Mobility I

Intercity Bus

- Technologies:
  - Ongoing research and test runs with electric and hydrogen powertrains
  - Expected to shape the future
- Advantages:
  - Low emissions
  - Low price
    → Well adapted to target customers: Low budget & green traveller segment
- Disadvantages:
  - Low comfort
  - High travel time

Sources: Banister (2008); Burgdorf, Eisenkopf & Knorr (2018); Mordor Intelligence (2020); Prillwitz & Barr (2011); Volkswagen AG (2019)

Street: Intercity Mobility II

Intercity Bus

- Opportunities
  - Onboard productivity
  - Potential decrease in car ownership
- Threats
  - Autonomous driving
  - Electrification of passenger cars
- Outlook
  - Moderate growth predicted, but dependends heavily on the development of car and rail mobility

Sources: Banister (2008); Burgdorf, Eisenkopf & Knorr (2018); Mordor Intelligence (2020); Prillwitz & Barr (2011); Volkswagen AG (2019)

Street: Intercity Mobility III

Passenger Car

- Technologies:
  - EVs are expected to soon make up the majority of vehicles
  - Fully autonomous driving will not be market ready before 2050
- Advantages:
  - High comfort
  - Low perceived travel time
- Disadvantages:
  - High emissions
  - High upfront costs
  - No on-board productivity

Sources: Banister (2008); Burgdorf, Eisenkopf & Knorr (2018); Prillwitz & Barr (2011)

Street: Intercity Mobility IV

Passenger Car

- Opportunities:
  - Rising share of electric cars
    → Improving environmental impact of private cars
  - Autonomous driving
    → Enabling on-board productivity
- Threats:
  - Low on-board productivity in short-run
  - Low levels of car ownership due to urban regulations
    → Opportunities likely to offset threats in the long-run
- Outlook:
  - Car as most attractive mode, especially with future opportunities
  - Highly dependent on urban mobility concepts regarding car ownership

Sources: Banister (2008); Burgdorf, Eisenkopf & Knorr (2018); Prillwitz & Barr (2011)

Street: Intercity Mobility V

Carpooling: Little perspective due to excessive value of travel time

Mobility on Demand: Too expensive for intercity travels

Vehicle on Demand: Currently relatively expensive and unflexible; car sharing is not rolled out for intercity trips

- **Advantages:** Affordable intercity car transportation for non-car owners
- **Disadvantages:** More expensive individual trips than own car or intercity bus
- **Opportunities:** Decrease of car ownership levels creates a market gap for comfortable intercity travelling
- **Threats:** Potential difficulties in reliable on-ground operations & profitability
- **Outlook:** In case of decreasing car ownership levels, a market gap for a flexible and affordable vehicle on demand model for intercity transportation emerges

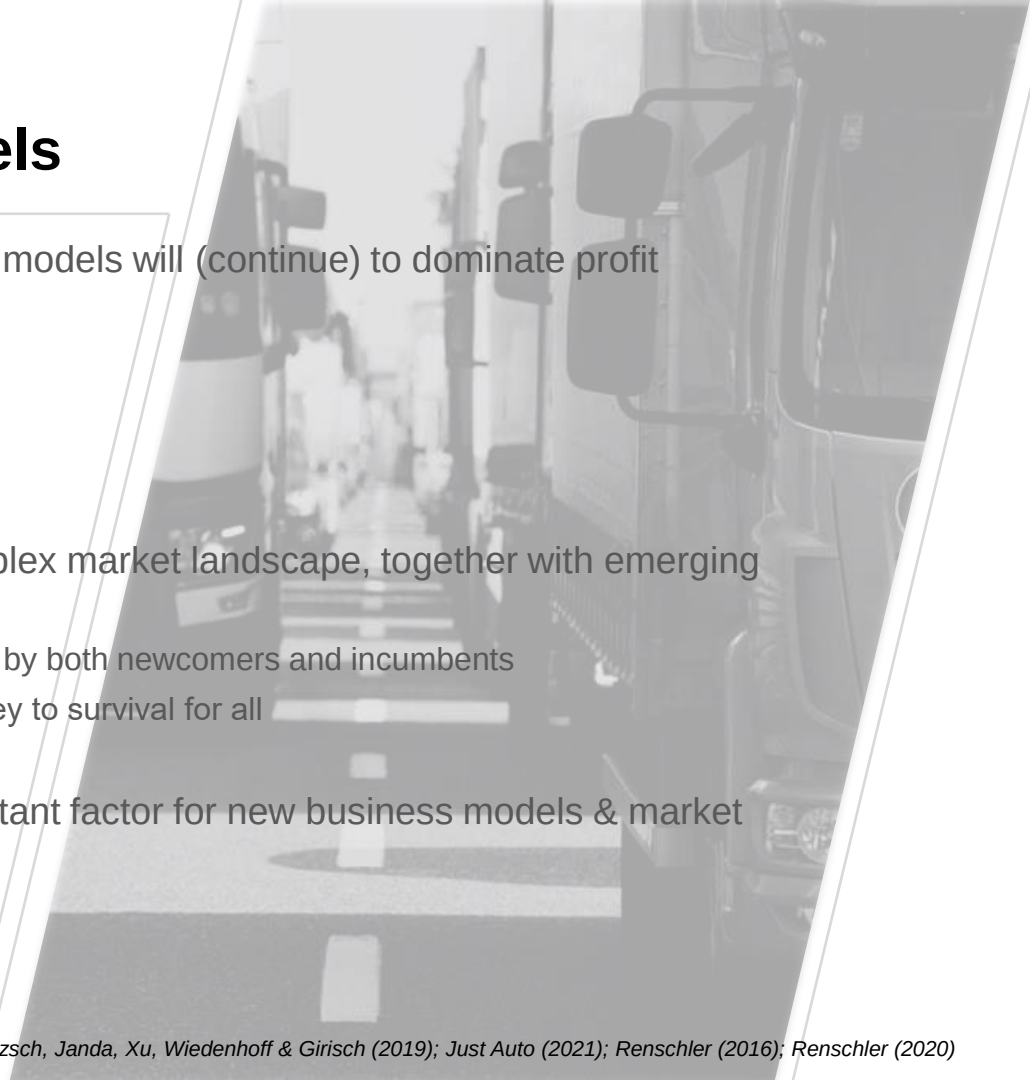
Sources: Burgdorf, Eisenkopf & Knorr (2018); Monchambert (2020); Uber (2021)

Street Cargo: Business Models

- After sales digital services & new business models will (continue) to dominate profit margins for OEMs
  - Battery leasing
  - Platooning ensemble (electronic binding)
  - Vehicle analytics, load & route optimisation

- OEMs will compete in an increasingly complex market landscape, together with emerging OEMs and service & mobility providers
  - Existing & new capabilities difficult to adopt by both newcomers and incumbents
  - Cooperation between “Auto plus Tech” is key to survival for all

- TCO (Total Cost of Ownership) most important factor for new business models & market viability



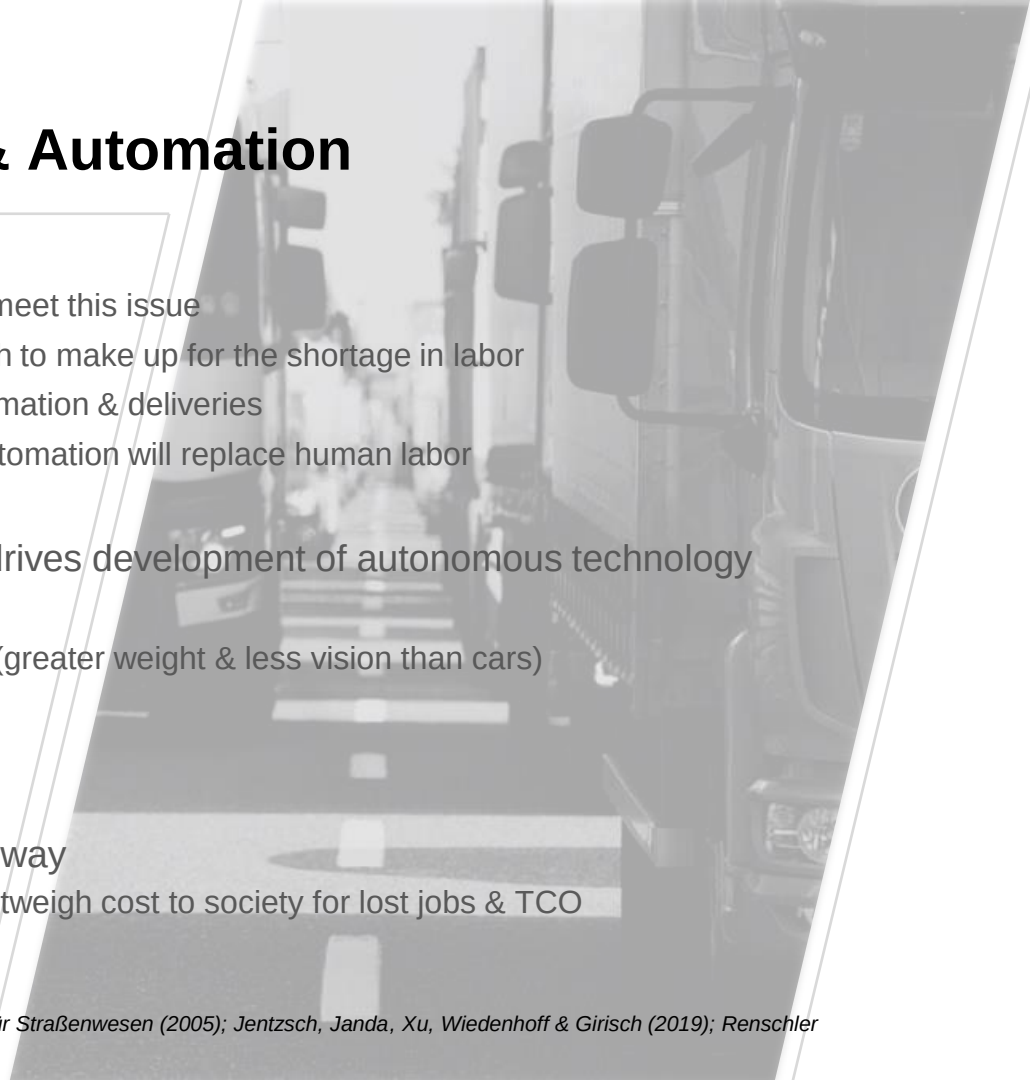
Sources: Electrek (2021); ENSEMBLE (2021); Fliesser (2019); Hyundai Motors (2021); Jentzsch, Janda, Xu, Wiedenhoff & Girisch (2019); Just Auto (2021); Renschler (2016); Renschler (2020)

Street Cargo: Infrastructure & New Powertrains

- (More) sustainable new powertrains:
  - Pure electric battery
  - Liquefied Natural Gas (LNG)
  - Hydrogen fuel cell
- All to achieve TCO advantage/exceed Diesel by 2030
- Sufficient supply chain & infrastructure needed for implementation
  - Fast-charging stations
  - Transport safety requirements (LNG & hydrogen)
  - Sufficient & reliable supply for regions without access to either LNG or hydrogen
- As energy density increases & distances decrease, frequency of charging stations need not be as high
  - Development of powertrains & supporting infrastructure need to go hand-in-hand
- Issues less challenging within cities
  - Use cases – light- and medium duty trucks
  - Shorter distances traveled

Sources: Electrek (2021); ENSEMBLE (2021); Fliesser (2019); Hyundai Motors (2021); Jentzsch, Janda, Xu, Wiedenhoff & Girisch (2019); Just Auto (2021); Renschler (2016); Renschler (2020)

Street Cargo: Labor Market & Automation



- CV driver shortage in Germany
  - Development of AD technology is rising to meet this issue
  - However, automation not developed enough to make up for the shortage in labor
  - Drivers still needed for current level of automation & deliveries
  - Strong political topic in face of fears that automation will replace human labor
- Self-reinforcing cycle
  → Expectation of growing driver shortage drives development of autonomous technology
- The case for automation:
  - Fewer fatal road accidents caused by CVs (greater weight & less vision than cars)
  - More precise driving & less downtime
  - TCO advantage
    → Greatest cost to fleets is labor
- Gradual shift towards full automation underway
  - But gained utility from automation has to outweigh cost to society for lost jobs & TCO
  - Last-mile transport will still require labor

Sources: APTIV (2020); BMVI (2021c); Daimler (2019); Evers, Auerbach & Bundesanstalt für Straßenwesen (2005); Jentzsch, Janda, Xu, Wiedenhoff & Girisch (2019); Renschler (2020); Toll Collect (2018)

Street Cargo: TCO & Adoption

- As of now, Diesel combustion engines remain most cost effective
  - Existing OEM capabilities (motor production)
  - Resource availability
  - Infrastructure & recharging costs
- Popularity of other powertrains determined by numerous factors:
  - Types of energy and their supply & availability
  - Manufacturing capabilities
  - Sufficient infrastructure
  - Regulation and economic incentives
- Battery electric vehicles (BEVs) most affordable alternative
  - Given steady & affordable energy prices
  - Especially for light- and medium duty trucks (energy density, weight of battery)
- LNG is a medium-term alternative
  - Quick refuelling capabilities, fewer emissions, favorable prices
  - Not a “clean” technology
- Hydrogen fuel cell is the ultimate goal for long-distance heavy-duty trucks

Sources: Heid, Martens & Orthofer (2021); Jentzsch, Janda, Xu, Wiedenhoff & Girisch (2019); Williams & Minjares (2016)

Street Cargo: Use Cases & Outlook

- Light commercial vehicles
  - Predicted last to adopt AD technology
    → Complex city traffic situations, delivery requiring human intervention
  - Most likely to adopt battery powertrains by a wide margin
    → Shorter distances, lighter loads
- Medium-duty trucks
  - More likely to adopt AD technology
    → Inter-city transport
  - Mix of LNG & battery powertrains likely, depending on distance
- Heavy-duty trucks
  - Most likely to adopt AD technology
    → Long-distance highway transport easiest & most cost effective to automate
  - Likely to be last to adopt new powertrains
    → Efficacy still needs development
  - Weight of batteries in relation to energy density must be optimised
  - Charging/refueling infrastructure not sufficient for long-distance transport
  - Will be greatest contender for hydrogen fuel cell in the future

Sources: ENSEMBLE (2021); Fliesser (2019); Jentzsch, Janda, Xu, Wiedenhoff & Girisch (2019); Renschler (2020); Volkswagen AG (2019)

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Rail: Status Quo I

- Railway system widely neglected for decades
  - Prioritization of roads & cars
- Lack of investments & innovation
  - Unattractive for private investors
  - Barely new business models
  - Time-worn rails & trains, fragmented rail system
- Missed opportunities in enhancing greener mobility
- Characterized by rigid processes and inflexibility
  - Incompatible with consumers' desire for individuality
- Difficulties in unifying national railway systems
- Disadvantaged compared to other means of transportation
  - High taxes, tolls & energy transfers
  - Results in high prices for customers

Sources: ADAC (2020); Allianz pro Schiene; BMVI (2021a); BMW (2020); European Commission (2021); Gräfe, A. (2014); Heinrich Böll Foundation (2021); Höhnscheid, H. (2019); Plattform Urbane Mobilität (2020); VDV(2021)

Rail: Status Quo II

- Consumers & governments increasingly acknowledge advantages of rail mobility
  - Electrification, usage of renewable energies, re-using braking energy
    → Trains only account for 0.4% of the EU's overall transportation greenhouse gas emissions
  - Safety
  - Low levels of noise pollution

- 2021 announced as "European Year of Rail" to promote rail transportation
  - Biggest challenges: electrification gaps & harmonization of national systems
    → Currently, 54% of Europe's railway lines are electrified

- Most promising means of transport in accordance with EU Green New Deal

Sources: ADAC (2020); Allianz pro Schiene (n.s.,a); BMVI (2021a); BMW (2020); European Commission (2021); Gräfe, A. (2014); Heinrich Böll Foundation (2021); Höhnscheid, H. (2019); Plattform Urbane Mobilität (2020); VDV(2020)

Rail: Urban & Short-Distance I

- Rail travel well adapted to urban needs
  - Many cities still employ trams, subways, & overground light-rail
  - Subways particularly useful
    → Operate entirely separated from overground traffic
    → High frequency & passenger volumes
    → No noise, air pollution, or congestion

- Diesel driving bans are likely to boost urban rail transportation
  → Challenge: cater to increasing demand with limited capacities
  → Opportunity: further improve air quality in cities

- Innovation desert: no new business models developed in decades
  → Must be supported by policy makers & governments

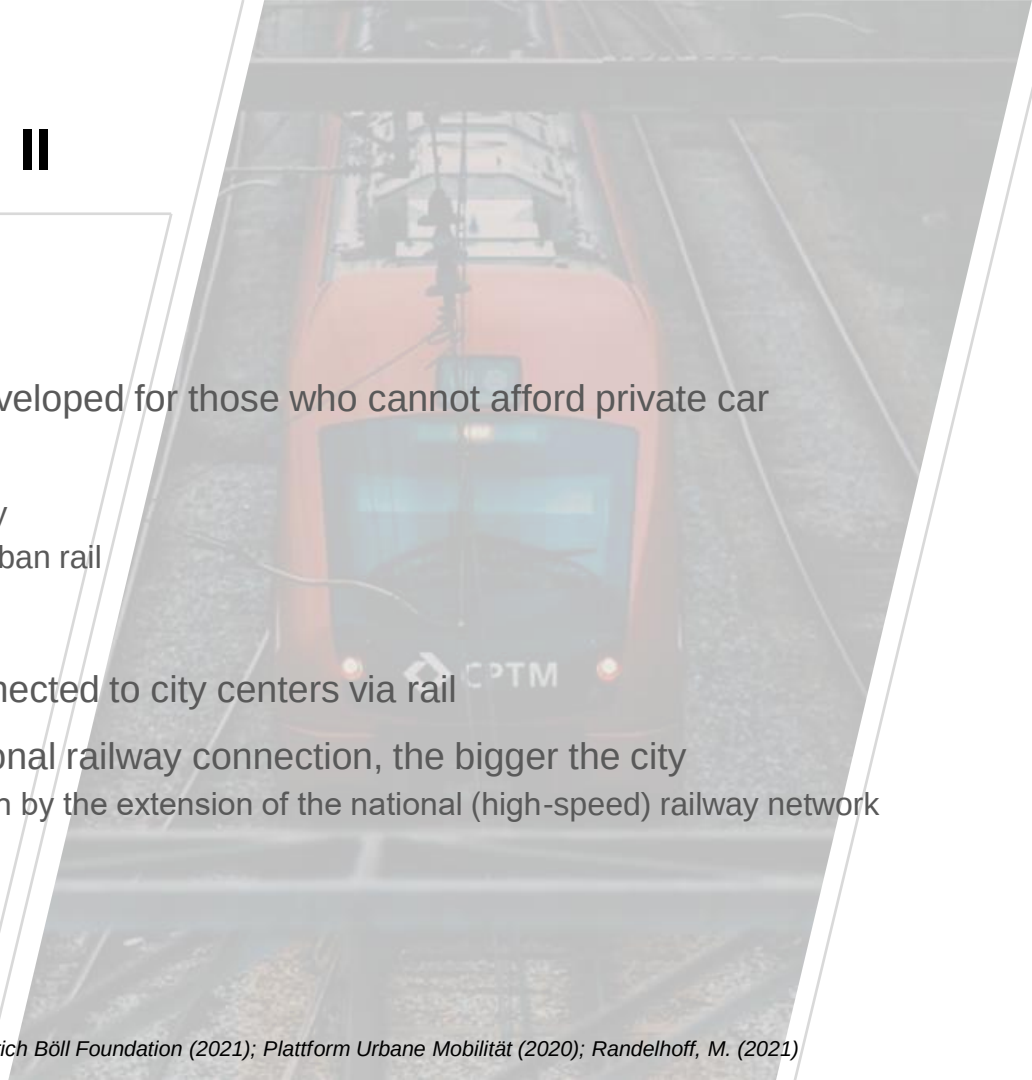
Sources: Brand, D. (2019); IEA (2019)

Rail: Urban & Short-Distance II

Political Perspective

- Public transport historically rudimentary developed for those who cannot afford private car
- Cities developed to be optimal for cars
  → Other modes of transportation had to make way
  → Difficult to change city architecture to benefit urban rail

- Especially rural areas are often poorly connected to city centers via rail
- Influences size of cities: the better the national railway connection, the bigger the city
  → China’s economic growth has partly been driven by the extension of the national (high-speed) railway network



Sources: Allianz pro Schiene (n.s.,b); BMW (2020); Brand, D. (2019); Götz, S. (2021); Heinrich Böll Foundation (2021); Plattform Urbane Mobilität (2020); Randelhoff, M. (2021)

Rail: Urban & Short-Distance III

Consumer Perspective

- Despite good fit, many Germans refrain from using urban rail
- In many German cities, taking public transportation doubles travel time vs. private car
- Significant percentage of Germans is not well connected to railway lines
  → Highest share: 21% (Mecklenburg-Vorpommern)
- Rail is one of the most expensive modes of transportation
  → Prices continue to increase: +16% between 2010 & 2020
- Often deemed too inflexible
- Overly complicated, analog processes
- Western countries should take Japan and China as railway role models
  - Convenient conditions for passenger trains
  - High reliability
  - Technically advanced

Sources: ADAC (2017); Allianz pro Schiene (n.d.); Bartels, J. (2016); Beil, P. (n.s.); Götz, S. (2021); Heinrich Böll Foundation (2021); Mobility Institute Berlin (2021)

Rail: Long-Distance I

- Biggest issue: electrification gaps
  → EU-average of railway electrification: 54%
  → Especially short-distance passenger routes lack electrification
  → On routes without overhead wires, diesel-powered trains must be used
  → Solutions: Investments in electrification
  Development of hybrid trains and alternative powertrains

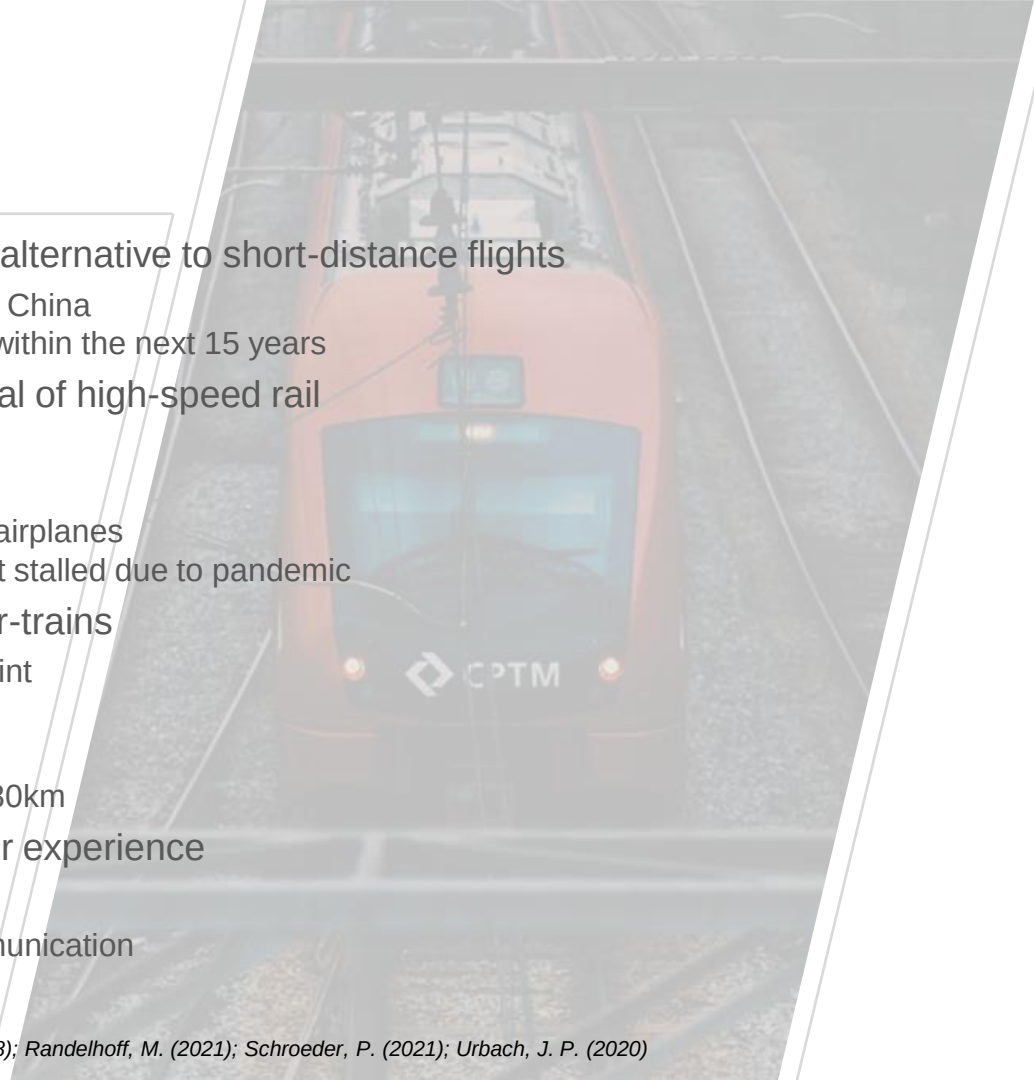
- EU plans to promote the progress of European railways
  - Development of Single European Railway Area
  - Open & restructure the market, increase competitiveness, improve efficiency & infrastructure

- Progress of rails critical for the future
  - Global demand for transport expected to more than double by 2050
  - Greater energy demand, increased emissions & atmospheric pollutants
  - Must invest in multilateral communication systems, automation, & electrification

Sources: BMVI (2021a); Council of the European Union (2021); German Aerospace Center (2021); IEA (2019)

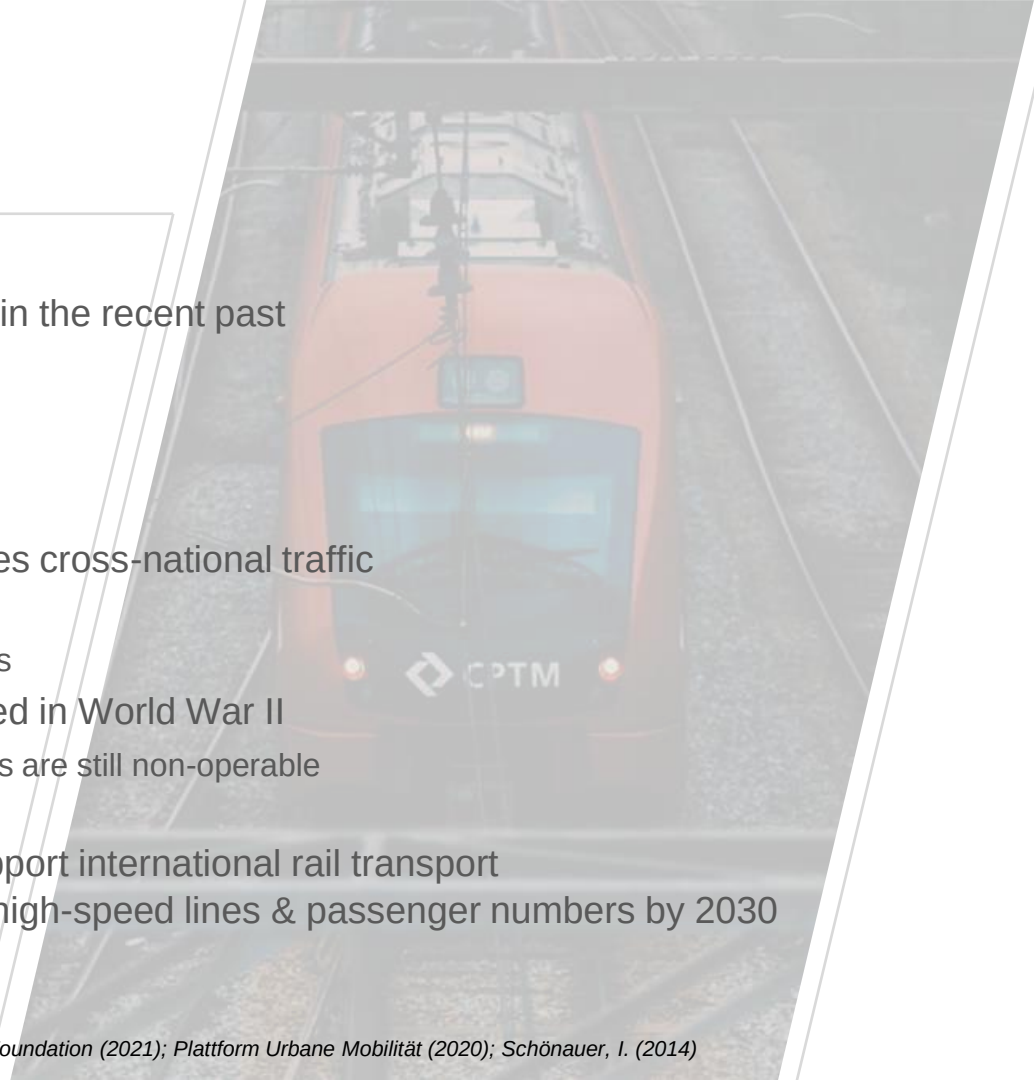
Rail: Long-Distance II

- High-speed trains should be developed as alternative to short-distance flights
  - ⅔ of all global high-speed rails are found in China
    → Plans to double the size of the network within the next 15 years
- Various business models prove the potential of high-speed rail
  - Aerotrain: maximum speed of 500km/h
    → Planned start of operation: 2025
  - Link & Fly: hybrid vehicle merging trains & airplanes
    → First presented in 2019 but development stalled due to pandemic
- Progress in developing of alternative power-trains
  - Fuel-cell based hydrogen trains: Coradia iLint
    → Inaugurated in Germany in 2018
  - Battery-electric trains
    → Can bridge electrification gaps of up to 80km
- New business models enhancing consumer experience
  - On-board infotainment systems
  - Enhancement of passenger-operator communication



Sources: Allianz pro Schiene (n.s.,a); BMVI (2021a); futureRAIL (n.s.); Kempkens, W. (2018); Randelhoff, M. (2021); Schroeder, P. (2021); Urbach, J. P. (2020)

Rail: Long-Distance III



Political Perspective

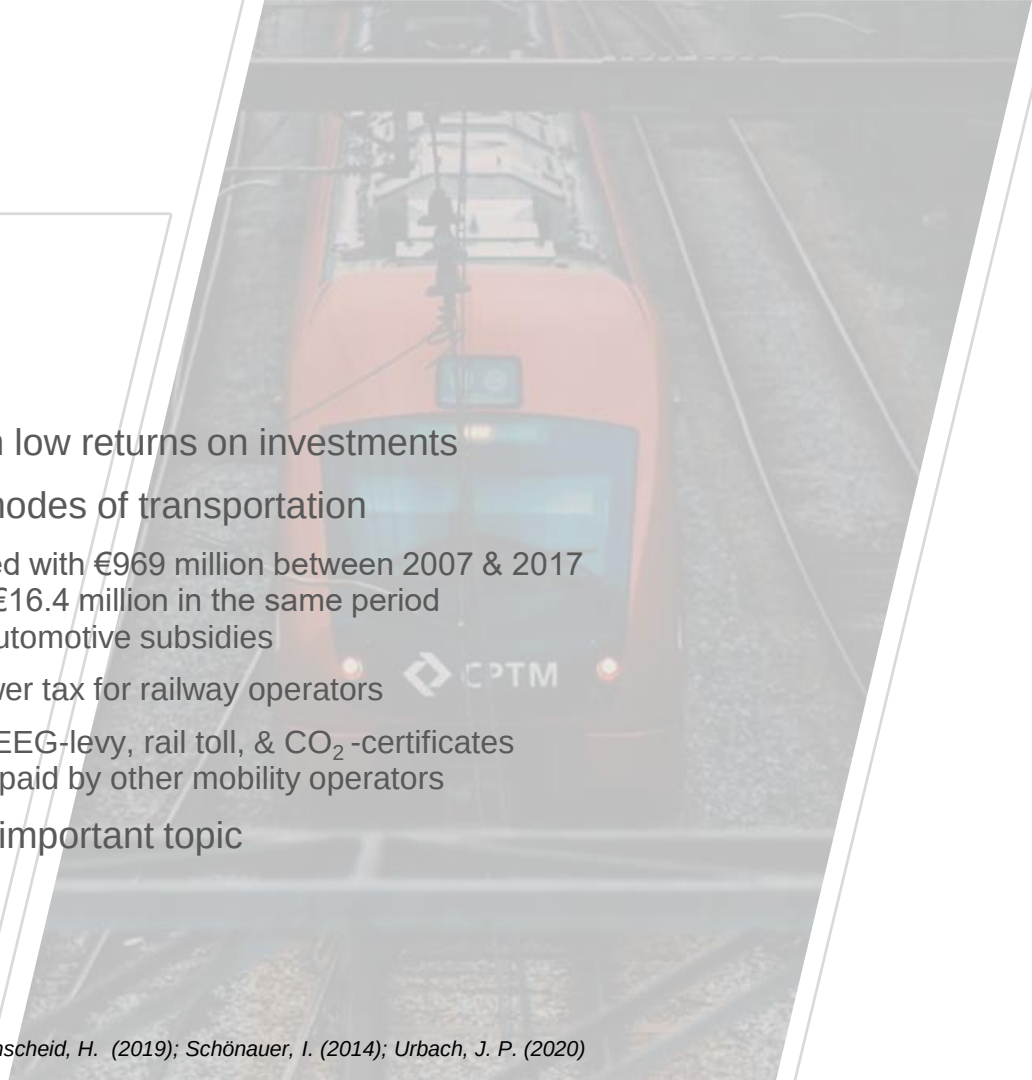
- The European railway network has shrunk in the recent past
  → Despite increasing demand & traffic
  - Germany: -14% between 1994 & 2020
  - Passenger traffic: +50%
  - Goods traffic: +90% in the same period
- Dissimilarity of national systems complicates cross-national traffic
  - Different track widths
  - Varying security, braking, & energy systems
- Critical cross-border infrastructure destroyed in World War II
  - 149 out of 365 cross-border rail connections are still non-operable
  - Affects ⅓ of the EU-population
- Need to develop common standards to support international rail transport
  → Single European Railway Area: double high-speed lines & passenger numbers by 2030

Sources: Allianz pro Schiene (2020); Council of the European Union (2021); Heinrich Böll Foundation (2021); Plattform Urbane Mobilität (2020); Schönauer, I. (2014)

Rail: Long-Distance IV

Political Perspective (continued)

- Significant lack of investors
  → High investment volumes combined with low returns on investments
- National governments still prioritize other modes of transportation
  - Germany: Automotive industry subsidized with €969 million between 2007 & 2017
    Rail industry subsidized with €16.4 million in the same period
    → Railway subsidies account for 1.7% of automotive subsidies
  - European governments charge highest power tax for railway operators
  - Highest extra costs for operators: eco-tax, EEG-levy, rail toll, & CO_2 -certificates
    → Most of them are not at all or only partly paid by other mobility operators
- Cybersecurity is becoming an increasingly important topic



Sources: Allianz pro Schiene (n.s., c); Allianz pro Schiene (n.d., d); futureRAIL (2021); Höhnscheid, H. (2019); Schönauer, I. (2014); Urbach, J. P. (2020)

Rail: Long-Distance V

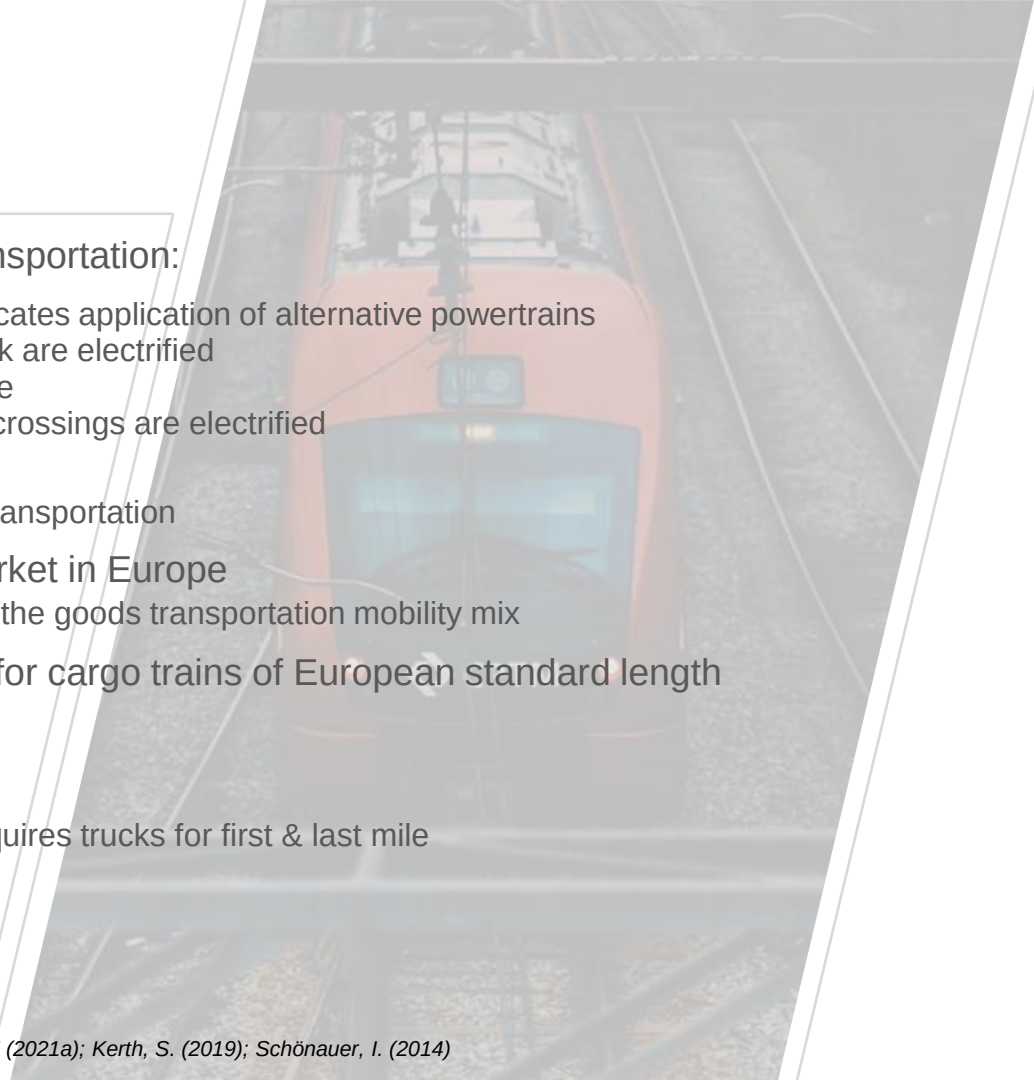
Consumer Perspective

- German consumers travel 10x more by car than by railway
  - Share of passengers on rails has remained stable at ~8% for decades
- Trains operated by Deutsche Bahn are often delayed / cancelled, have technical problems & quality deficiencies, & are expensive
- Germany invests far less per person per year in rail transport than other European countries
  - Germany: €88
  - Switzerland: €440
  - Luxemburg: €567
- COVID-19 pandemic expected to have serious impact on financing of public transportation in medium-run
- Limited interoperability between national systems makes trains unattractive

Sources: Allianz pro Schiene (2020); Allianz pro Schiene (n.s., c); Allianz pro Schiene (n.s., d); Fishman, T., Kelkar, M., Schwartz, A. (2020); Heinrich Böll Foundation (2021); Höhnscheid, H. (2019); Plattform Urbane Mobilität (2020); Poggi, A., Barbieri, G., Onorato, L. (2019)

Rail: Cargo I

- Main challenges to international freight transportation:
  - Lack of electrification: heavy weight complicates application of alternative powertrains
    → Currently, 54% of the EU railway network are electrified
    → Diesel remains the primary power-source
    → Within the EU, only 27 out of 57 border crossings are electrified
  - Incompatible national railway systems
    → Increases costs for international cargo transportation
- Germany is the largest cargo rail traffic market in Europe
  → But has one of the lowest shares of railways in the goods transportation mobility mix
- 90% of German railway network unusable for cargo trains of European standard length
  → passing tracks either too short or non-existent
- Time-consuming processes
  - Lack of direct access to industrial parks requires trucks for first & last mile
  - EU systems still rely on manual coupling



Sources: Allianz pro Schiene (n.s., a); Allianz pro Schiene (n.s., e); Bartels, J. (2016); BMVI (2021a); Kerth, S. (2019); Schönauer, I. (2014)

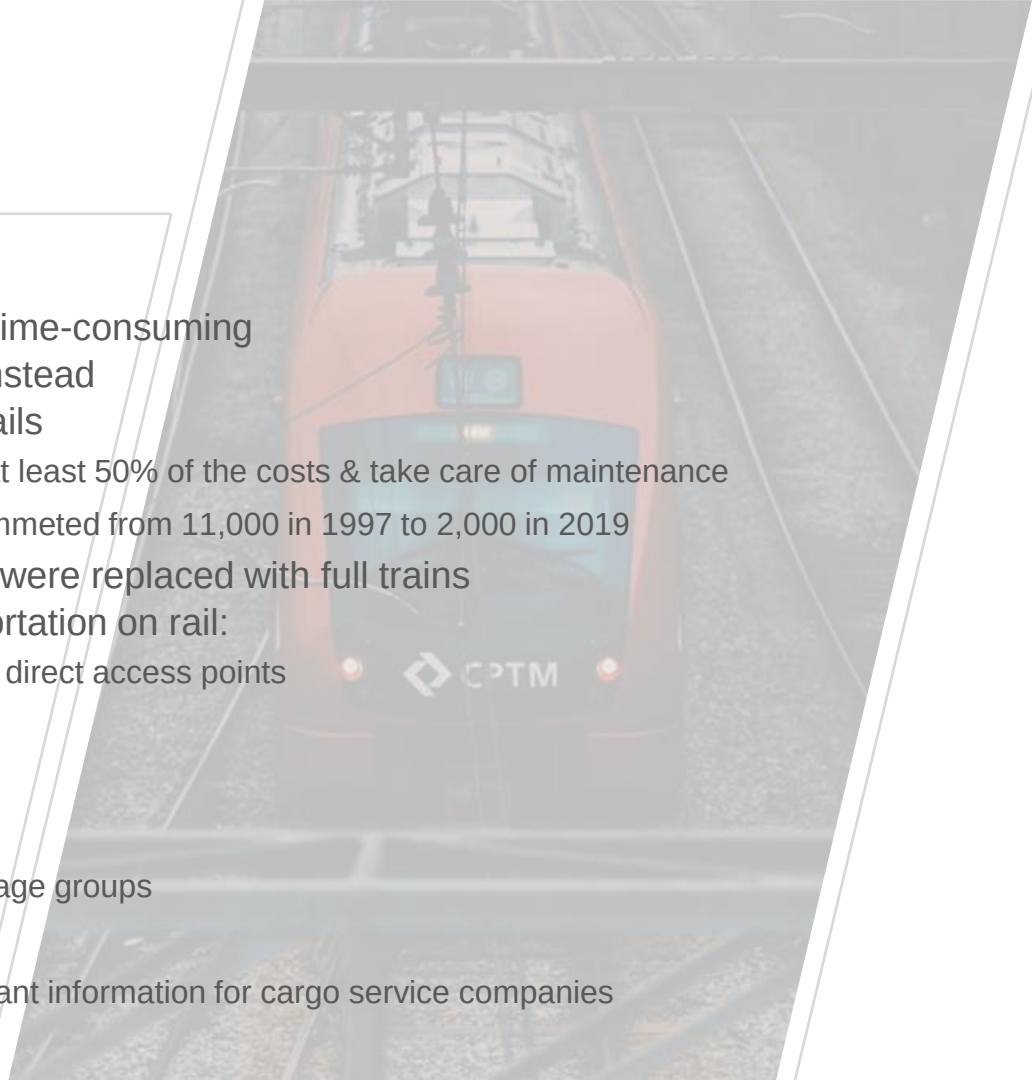
Rail: Cargo II

Political Perspective

- Cargo Rail as part of the European Green New Deal
  - Increase share of goods transportation on rails from 19% (2019) to >25% by 2030
- Germany lags far behind in employment of cargo trains
  - Austria: already reached 25% rail transportation in 2019
  - Switzerland: 40% cargo transportation on rails in 2019
- In the past, declarations of intent often did not trigger actions
  - In 2017, Germany developed a “Masterplan for rail freight transport”
  - Aims: Improve competitiveness, increase market share, modernize cargo rail sector
  - Funding approved by the federal government was never allocated in the state budget of 2019
- Actively disadvantaged vs. other modes of transportation
  - Highest energy tax
  - Users are required to pay tolls
  - No governmental subsidies

Sources: Allianz pro Schiene (2020b); Allianz pro Schiene (n.s., a); Allianz pro Schiene (n.s., e); Bartels, J. (2016); BMVI (2021a); Kerth, S. (2019); Schönauer, I. (2014)

Rail: Cargo III



Consumer Perspective

- International transportation is money- and time-consuming
  → Freight companies often opt for trucks instead
- Industry parks often lack direct access to rails
  - Companies requesting access must carry at least 50% of the costs & take care of maintenance
  - Share of companies with direct access plummeted from 11,000 in 1997 to 2,000 in 2019
- Individuality has suffered: Single carriages were replaced with full trains
- Necessary steps to promote freight transportation on rail:
  - Improve general conditions for operators of direct access points
  - Cut down bureaucracy
  - Cut costs & risks
  - Offer subsidisations
  - Reintroduce single carriages / smaller carriage groups
  - Automate coupling
  - Increase transparency considering all relevant information for cargo service companies

Sources: Allianz pro Schiene (2020b); Allianz pro Schiene (n.s., b); Lennarz, G. (2019)

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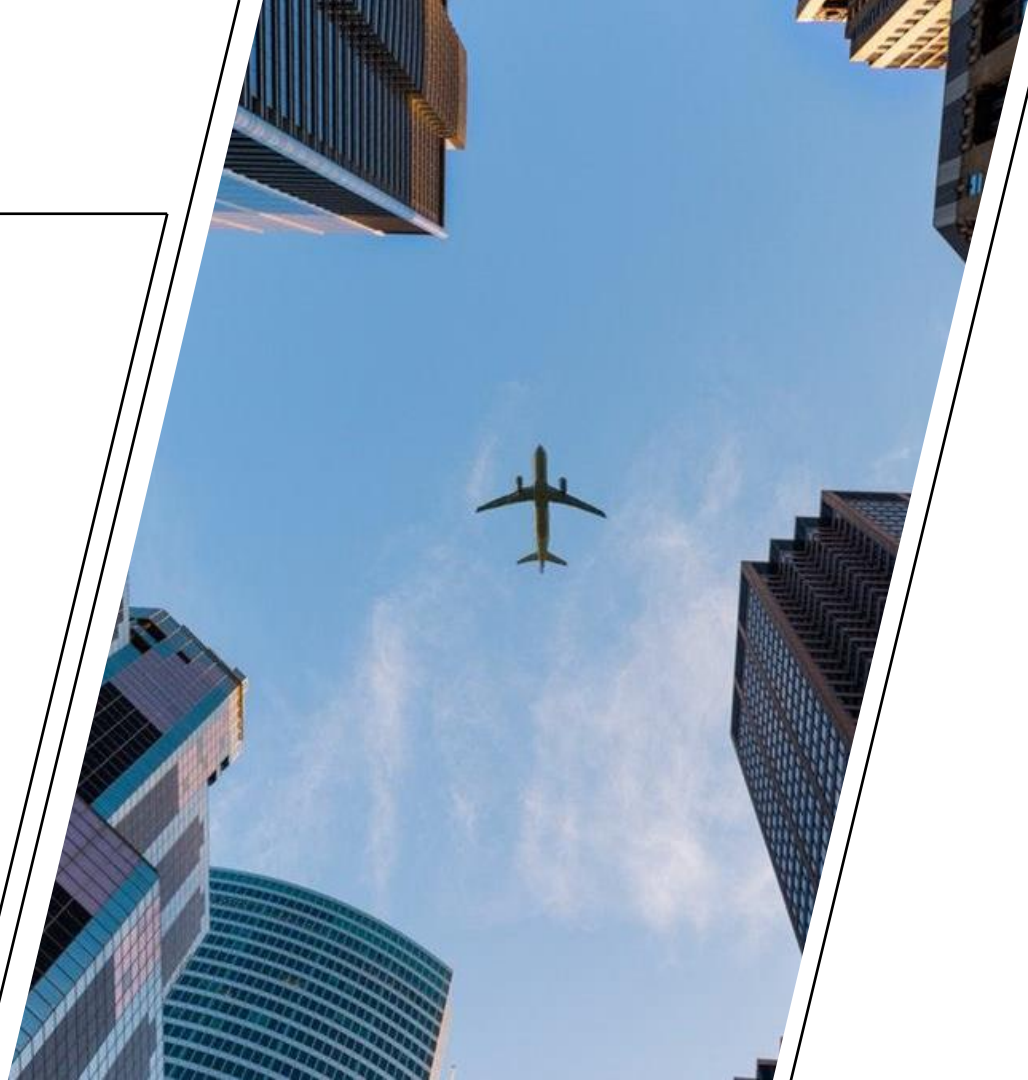

Aircraft: Long-Distance

- Airplanes are currently the most important provider of aerial mobility
- Existing aircrafts are difficult to be technologically upgraded, esp. in terms of propulsion system
- Long-distance flights as they exist today will be just as (or more) important for the next decades
- **But**: Changes to current business models will be necessary for airlines
- Cargo and passenger planes could profit from further digitization of its sales processes
- Ecological factors as well as the COVID19-pandemic influence the way consumers view long-distance aerial travel

Sources: Baraniuk (2020); Bouwer et al. (2021); Destatis (2021); Gillen (2006); IATA (2018)

Aircraft: Urban I

- Fully electric short-distance aircrafts (drones) are being heavily researched
- Urban Aerial Mobility (UAM) for people and cargo:
  - For people: passenger drones / air taxis
  - For cargo: delivery / cargo drones
- Success of UAM depends on acceptance level of citizens
  - Acceptance levels on the rise from generation to generation (SOURCE)
  - Transparancy can further increase acceptance

Sources: Deloitte (2020); Lyon-Hill et al. (2020); Shepardson (2021); Volocopter (2021a)

Aircraft: Urban II

- Biggest challenge of commercial drone traffic is regulation and infrastructure
  - Safety, Security and Liability to be defined in new legislation
  - Setting up the necessary starting, charging and landing platforms for VTOL
- Drones are likely to rapidly gain relevance in cargo transport, esp. Last mile delivery
- Establishment of delivery drones could decrease road usage and reduce CO_2 emissions
- Passenger drones might see first application as airport shuttles, commuting from outer-city airports to certain inner-city destinations

Sources : Lyon-Hill et al. (2020); Shepardson (2021); Volocopter (2021a)

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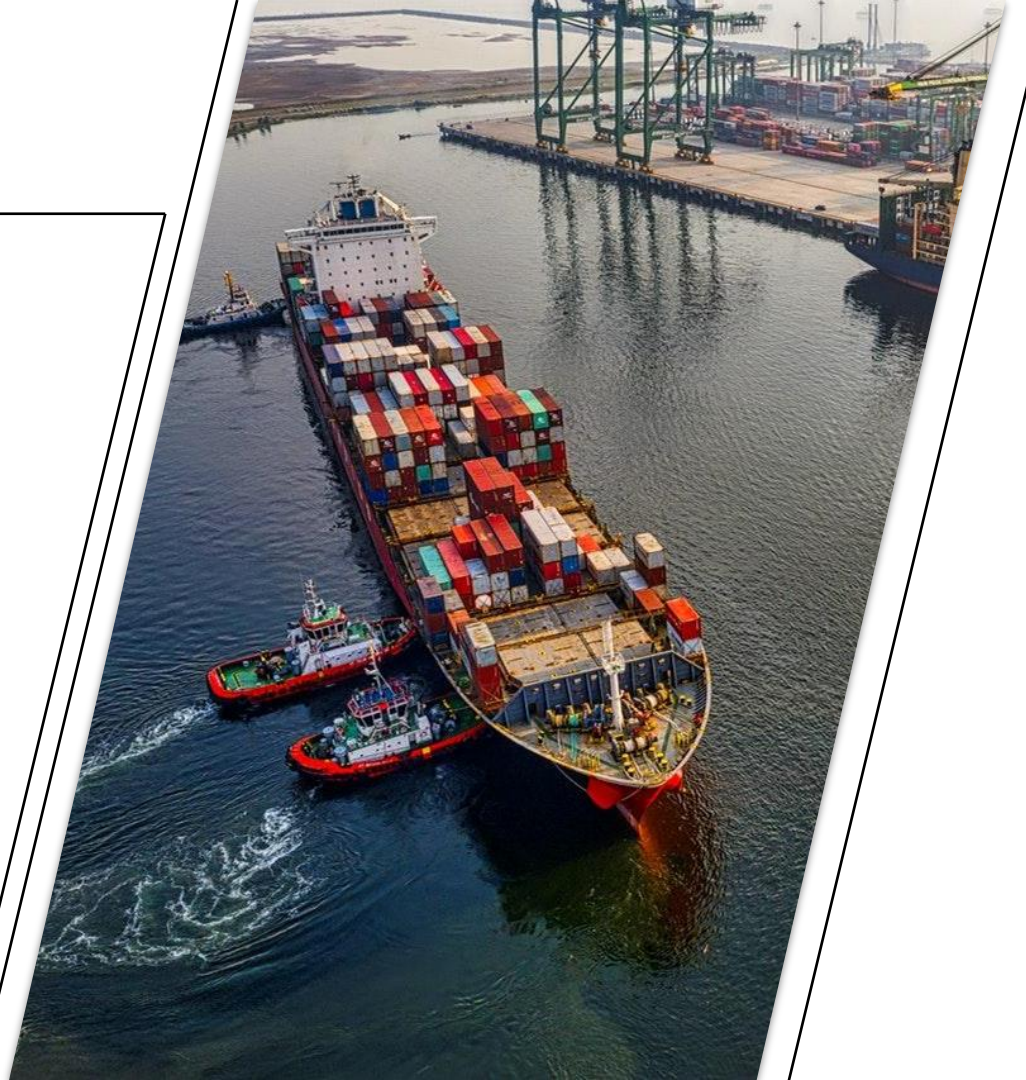

Ship

- Current maritime transport heavily relies on crude oil (> 90%)
- Maritime transport with very large share of harmful emissions globally
- Cargo transport on waterways accounts for 90% of global tonnage of goods traded
- Also relevant (but less) for mobility of people (e.g. ferries)
- Electric/Hybrid propulsion systems on the rise for smaller vessels
- Disruption in propulsion of cargo and container ships very unlikely in the near future
- Small innovations possible with targeted legislation

Sources: DLR (2011); DNV (2020); DNV GL (2019); IMO (2020); Oceana (n.s.)

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Hyperloop I

- First mentioned in 1810
  → Brought back to the spotlight by Elon Musk in 2013
- Highly ambiguous
  - Proponents call it the solution to many of today‘s transportation problems
  - Opponents consider costs, technical hurles, & required efforts too large to be balanced out by potential benefits
- Development efforts are particularly concentrated in Europe & Asia

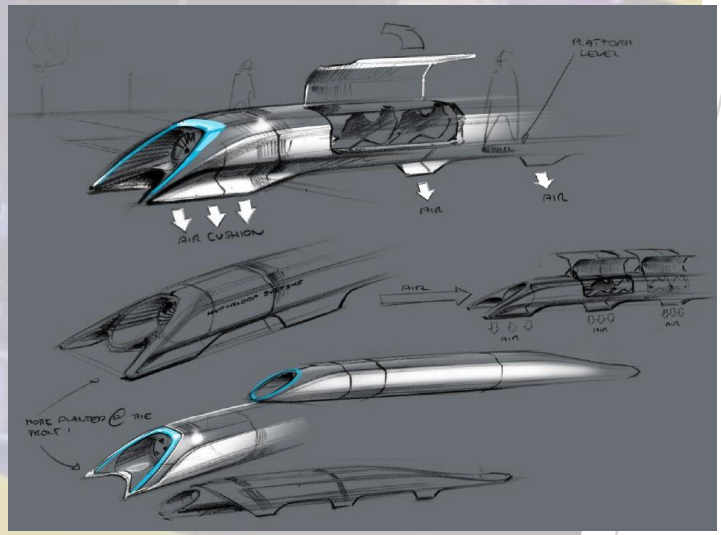
Technologies:

- Need long time to accelerate & de-accelarate
  → Only applicable for long-distance travel
- Low-drag, low-pressure tunnel systems (quasi-vacuum)
- Over- or underground
- Pods driving through tubes at supersonic speeds, on air cushions or magnetic fields
  → This would make hyperloops 15x faster than regular trains
- Stations must consist of three parts to maintain the vacuum within the tubes

Sources: Chicago Tribune (2020); Janczura, S. (2021); Knecht, J. (2021); Mitropoulos, L. et al., (2021); Musk, E. (2013); Noland, J. K. (2021); Silk, R. (2021); Stoller, D. (2018); Urbach, J. P. (2020); van Goeverden, K. et al. (2018); Variyar, M. (2020); Wadke, R. (2020); Walker, R. (2018)

Hyperloop II

- First mentioned in 1810
  → Brought back to the spotlight by Elon Musk in 2013
- Highly ambiguous
  - Proponents call it the solution to many of today‘s transportation problems
  - Opponents consider costs, technical hurles, & required efforts too large to be balanced out by potential benefits
- Development efforts are particularly concentrated in Europe & Asia
  → Lead 80% of all current developments



Source: Musk, E. (2013)

Sources: Chicago Tribune (2020); Janczura, S. (2021); Knecht, J. (2021); Mitropoulos, L. et al., (2921); Musk, E. (2013); Noland, J. K. (2021); Silk, R. (2021); Stoller, D. (2918); Urbach, J. P. (2020); van Goeverden, K. et al. (2018); Variyar, M. (2020); Wadke, R. (2020); Walker, R. (2018)

Hyperloop III

Business Models

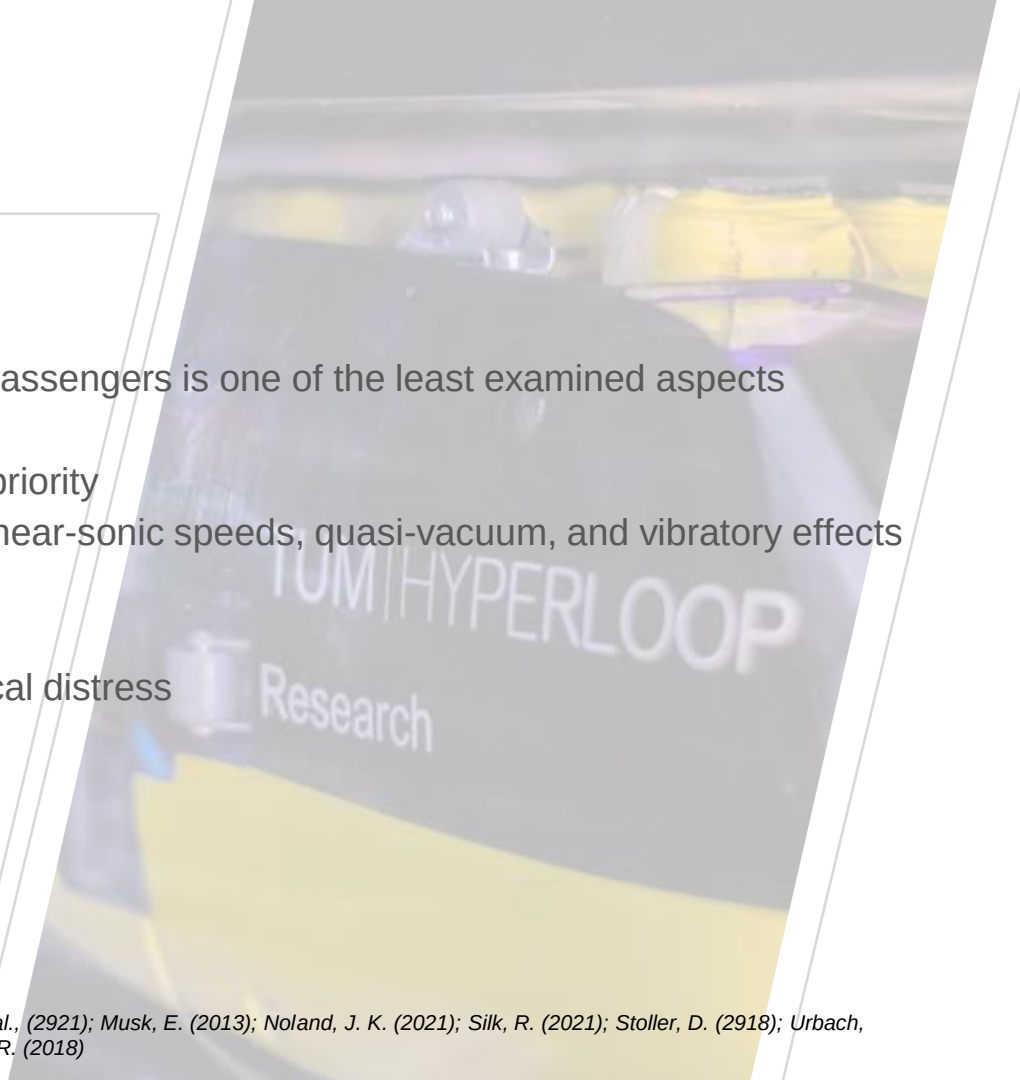
- Too early to have functioning business models
- Elon Musk planned to build a „Chicago Express Loop“
  - Tunnel system for high-speed buses connecting Chicago city center with Chicago O‘Hare airport
    → was never built
  - Instead, Musk built the „Vegas Loop“ connecting the convention centers in Las Vegas
    → Inaugurated in April 2021 but does not yet fulfill expectations
- Dutch company „Hardt“ planning to operate cargo hyperloops in 2025 & passenger hyperloops in 2028
  - Plan 5 international trajectories between the Netherlands, Belgium, France and Germany
- Richard Branson‘s „Virgin Hyperloop“ conducted the first ever manned test-drive in 2021
  - Only reached maximum speed of 140km/h
  - Commercial operation planned to start by 2030

Sources: Chicago Tribune (2020); Janczura, S. (2021); Knecht, J. (2021); Mitropoulos, L. et al., (2921); Musk, E. (2013); Noland, J. K. (2021); Silk, R. (2021); Stoller, D. (2918); Urbach, J. P. (2020); van Goeverden, K. et al. (2018); Variyar, M. (2020); Wadke, R. (2020); Walker, R. (2018)

Hyperloop IV

Consumer Perspective

- The impact of hyperloop transportation on passengers is one of the least examined aspects
- Passenger safety & comfort must be a top-priority
  → Effects of acceleration, de-acceleration, near-sonic speeds, quasi-vacuum, and vibratory effects on humans are still unknown
- Possibility of motion sickness & psychological distress



Sources: Chicago Tribune (2020); Janczura, S. (2021); Knecht, J. (2021); Mitropoulos, L. et al., (2921); Musk, E. (2013); Noland, J. K. (2021); Silk, R. (2021); Stoller, D. (2918); Urbach, J. P. (2020); van Goeverden, K. et al. (2018); Variyar, M. (2020); Wadke, R. (2020); Walker, R. (2018)

Hyperloop V

- Advantages:
  - Potential to be very green mode of transportation
  - Positive impact on economy and society
  - Expands people‘s working and living opportunities
  - Grants citizens access to larger pool of jobs, housing, healthcare, education, etc.
- Disadvantages:
  - Difficulty of maintaining vacuum over large distances
  - External influences: earthquakes, climate change, temperature differences
  - Unknown impact of vacuum & high speeds on passengers
  - Realisability of potential advantages still very vague
  - Need for extreme investments
  - Need for new infrastructure
  - Need for adaptation to exact geological conditions

Sources: Chicago Tribune (2020); Janczura, S. (2021); Knecht, J. (2021); Mitropoulos, L. et al., (2921); Musk, E. (2013); Noland, J. K. (2021); Silk, R. (2021); Stoller, D. (2918); Urbach, J. P. (2020); van Goeverden, K. et al. (2018); Variyar, M. (2020); Wadke, R. (2020); Walker, R. (2018)

Hyperloop VI

- Opportunities:
  - Could replace short-haul flights
  - Potentially greener & more energy-efficient than airplanes
  - Potentially very safe
  - Governmental support in the EU & USA
- Threats:
  - Must be adapted to each individual route
  - Lack of social acceptance
  - Large investments may limit the affordability
  - Highly immature technology
  - Usability of renewable energies yet to be proven
  - Incompatibility with current telecommunication networks
  - Need for entirely new regulations

Sources: Chicago Tribune (2020); Janczura, S. (2021); Knecht, J. (2021); Mitropoulos, L. et al., (2921); Musk, E. (2013); Noland, J. K. (2021); Silk, R. (2021); Stoller, D. (2918); Urbach, J. P. (2020); van Goeverden, K. et al. (2018); Variyar, M. (2020); Wadke, R. (2020); Walker, R. (2018)

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Outlook: Mobility of the Future I

*What are possible **changes** in mobility?*

*What could **hinder** advancements in mobility?*

*What are likely **developments** in business models?*

*How could mobility change from now to **2030**?*

*How could mobility change from now to **2050**?*

Outlook: Mobility of the Future II

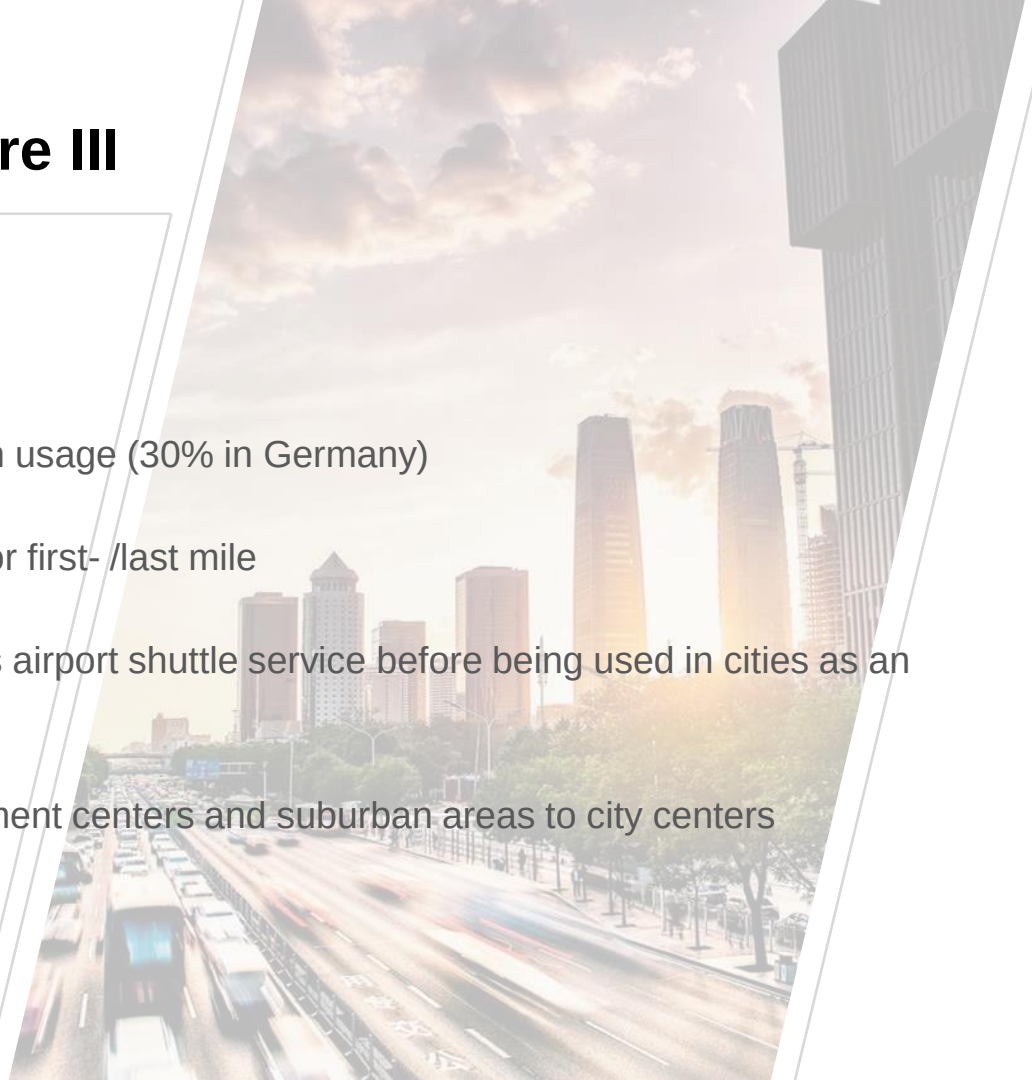
Vision of 2030

General

- Alternative fuels will be the basis for many different modes of mobility
- Electric Cars will replace gas cars, OEMs will likely phase out production of gas cars
- Multiple factors will influence the progress of rail transportation
  - Increasing acknowledgement of good fit for climate protection
  - Increasing regulations against private cars & traditional power-trains
  - Car-free city centers
  - Prohibition of domestic and short-haul flights
- Hyperloop technology is still too immature to be a viable transportation system
  - There will be no commercially operational hyperloop tracks by 2030 due to multiple reasons, e.g. investments too expensive, benefits too uncertain, impact on human unknown, non-existent infrastructure
  - Research will continue, Public acceptance will have to be further evaluated

Outlook: Mobility of the Future III

Vision of 2030



Urban

- Local Public Transport will see increases in usage (30% in Germany)
- Micromobility as complementary solution for first- /last mile
- Passenger drones could see application as airport shuttle service before being used in cities as an alternative to road and rail traffic
- electric and hybrid ferries connect employment centers and suburban areas to city centers

Outlook: Mobility of the Future IV

Vision of 2030

Intercity

- Cars are projected to persist as the most relevant mode for intercity mobility
- Trajectory of intercity buses is highly dependent on the developments in car ownership
  → sector projected to moderately grow
- Long-distance flights might be changed regarding hub networks, seating concepts and digitization
  → But: long road ahead for revolution of propulsion systems and commercial integration of alternative fuels
- Governments will give in to society‘s push and start subsidizing railway transportation
- Emerging new business models will increase the convenience and travel experience of rails which draws more passengers to trains
- The harmonization of national railway systems will promote people & goods transportation on rails

Outlook: Mobility of the Future V

Vision of 2030

Cargo

- LNG will take over Diesel combustion powertrains in terms of TCO benefit & a relative increase in sustainability
- Battery-based electric motors will have a high adoption rate for inner- and inter-city transport, especially light CVs but also medium-duty trucks
- Infrastructure, OEM capabilities & resources will have to be secured to cut costs & create TCO advantage
- Delivery Drones will be commercially ready for urban usage, success depends on:
  - Acceptance level of citizens
  - Status of connectivity & autonomy of drones
  - Establishment of necessary infrastructure

Outlook: Mobility of the Future VI

Vision of 2050

General

- Society‘s and economy‘s pace will keep accelerating
- Autonomous driving as enormous opportunity by offering onboard entertainment and productivity
  → Transformation of car to third places: Travel time might not be considered a cost anymore
- Hydrogen fuel cell will overtake LNG (& Diesel) for long-distance & heavy-duty use cases
- With more time passing and tireless research & development efforts of some stakeholders, some hyperloop routes will be operational
  - Expected to be particularly relevant in Asia
  - Connecting mega-cities via hyperloop
  - Changes people‘s prospects of living, working, health, education, etc.
  - Further boosts internationalization

  → **But**: will not be as energy-efficient as aspired & employment of hyperloop remains impossible in some regions

Outlook: Mobility of the Future VII

Vision of 2050

Urban

- Further increasing usage of local public transportation systems
- Autonomous driving for buses & first- / last mile shuttles as opportunity
- Profits from potentially car free city centers
- Passenger drones were successful as airport shuttles and are beginning to compete against taxis & public transport in cities
- Autonomous electric (or hydrogen) ferries are connected to cities public transportation systems and enable commuting between suburbs and city centers comfortably

Outlook: Mobility of the Future VIII

Vision of 2050

Intercity

- Relevance for intercity mobility highly depends on car ownership levels for urban residents
- Opportunity for vehicle on demand models for intercity transportation because of potentially decreasing car ownership levels
- Intercity buses will be most viable for low income segment
- Decreasing levels of car ownership as opportunity, but autonomous cars as threat to the significance of intercity buses
- The only remaining form of rail transportation will be high-speed rail
  → They replaced domestic and short-haul flights with traditional airplanes entirely

- Long-distance flights are executed by hybrid planes with novel seating concepts to enable a more social & comfortable flight
  → Restructuring of flight networks might result in connection of rail & air to reach specific hub for take-off

Outlook: Mobility of the Future IX

Vision of 2050

Cargo

- Adoption of hydrogen fuel cell in heavy-duty trucks (HDT) use cases heavily dependent on:
  - Development of supply chains & infrastructure
  - Stable & affordable prices & production costs
- Stage V autonomous driving technology should be applicable in many use cases, especially long-haul transport, HDTs and medium-duty trucks
  - Inner-city transport could also be automated, except for last-mile transport
- Goods are increasingly transported on rails but on individual units rather than on trains stretching for kilometers
  - Consumers‘ desire for flexibility and individuality will not decrease
- Delivery drones will be an established means of transportation for last- and first-mile delivery
  - Quicker, Cheaper and punctual delivery of cargo in general and emergency supplies (e.g. medicine) possible
- Cargo ships might be last mode of mobility to fully adopt alternative propulsion systems

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Implications for Automotive Manufacturers

- Speed up development for electric vehicles (especially battery technology), to make them a viable competitor for gasoline cars
- Repair the damaged reputation of the automotive industry (e.g. with CO_2 neutrality)
- Explore new revenue streams in the service business (subscriptions, entertainment, upgrades...)
- Work with public and private institutions (governments, tech providers, service providers) to define the role of cars in the future
- Industry consolidation through co-operations between OEMs, energy & telecommunication providers
- Invest in software solutions to bring car interfaces up to current standard of digital technolgy

Sources: Bloomberg (2021); Tesla (2021); Yu, A. & Sumangil, M. (2021)

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