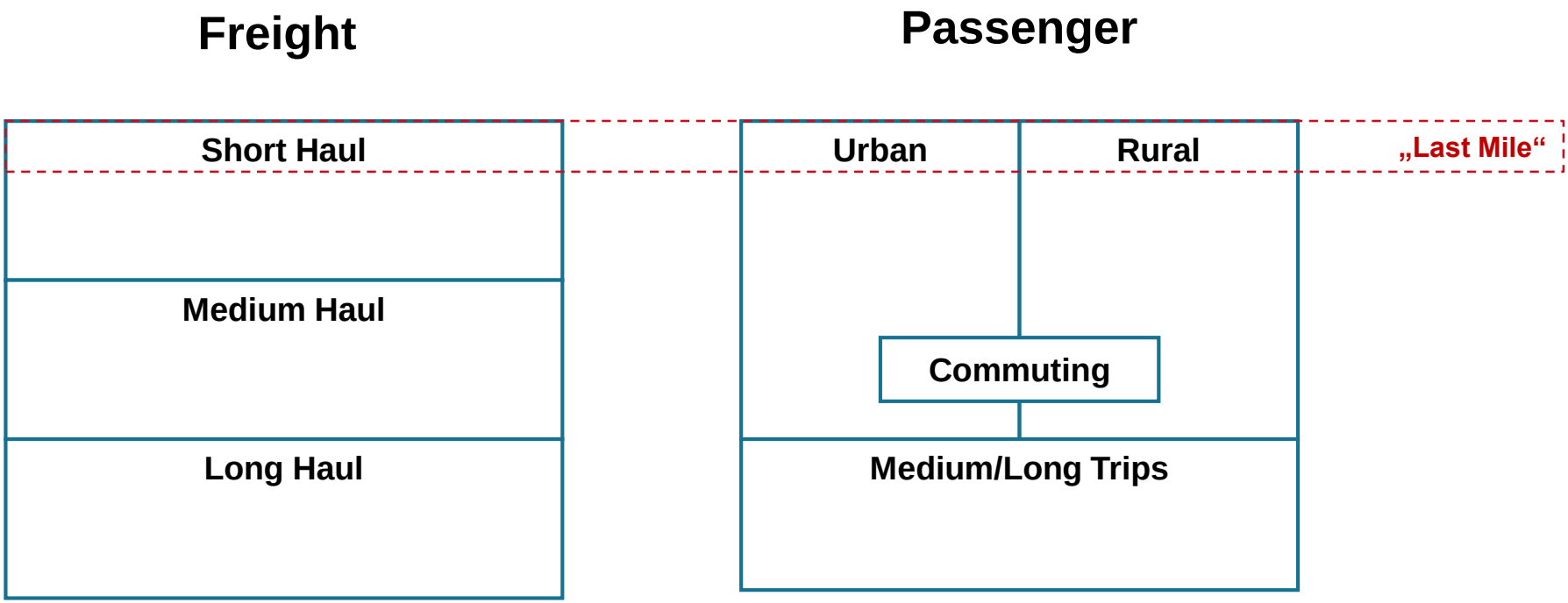
Some Thoughts on Strategies for Transport in the Age of Climate Change

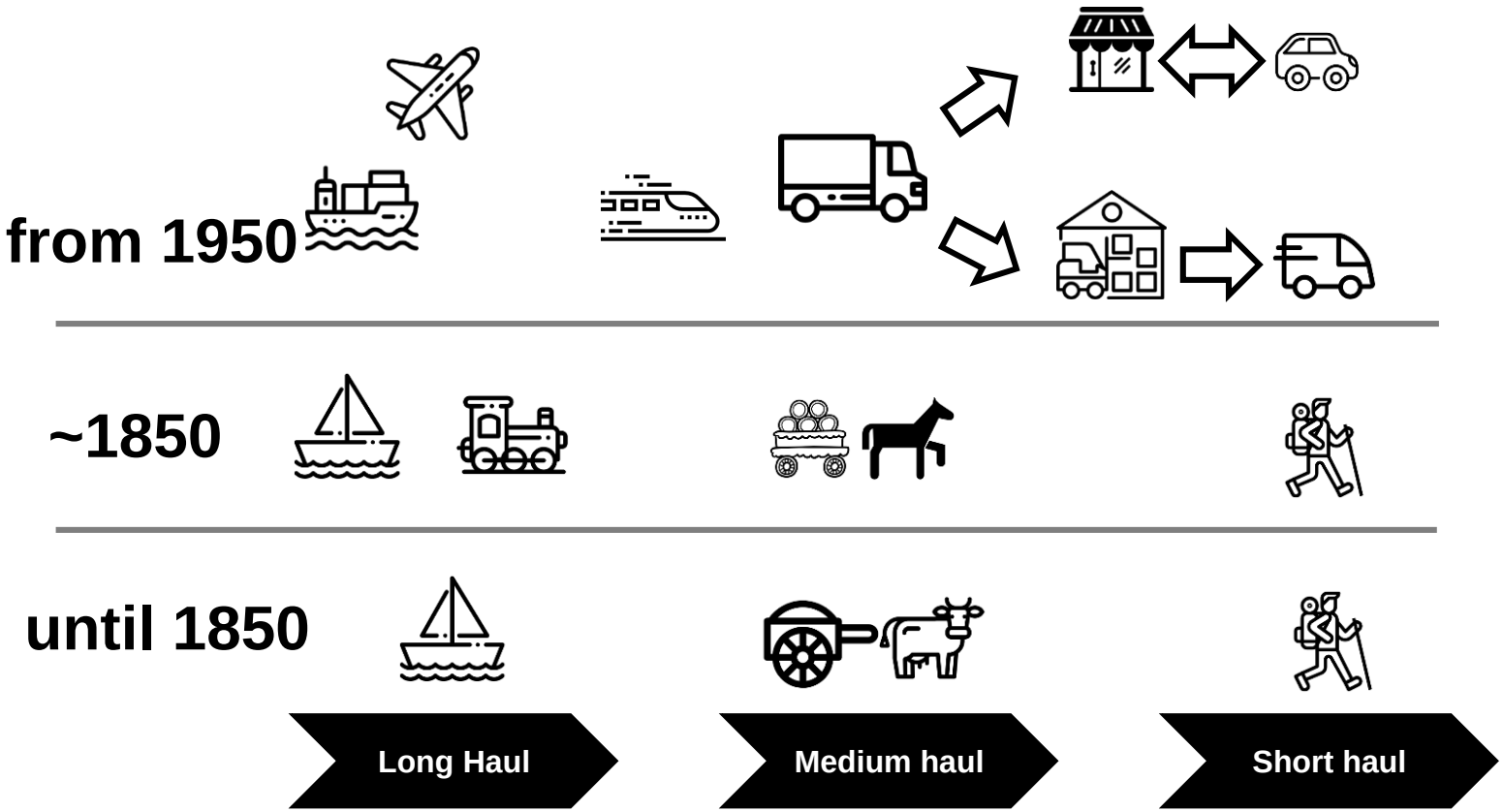
Christoph Henseler | TU Berlin, ArTe | REFORM Group Meeting 14.10.2019

Transport – systemic

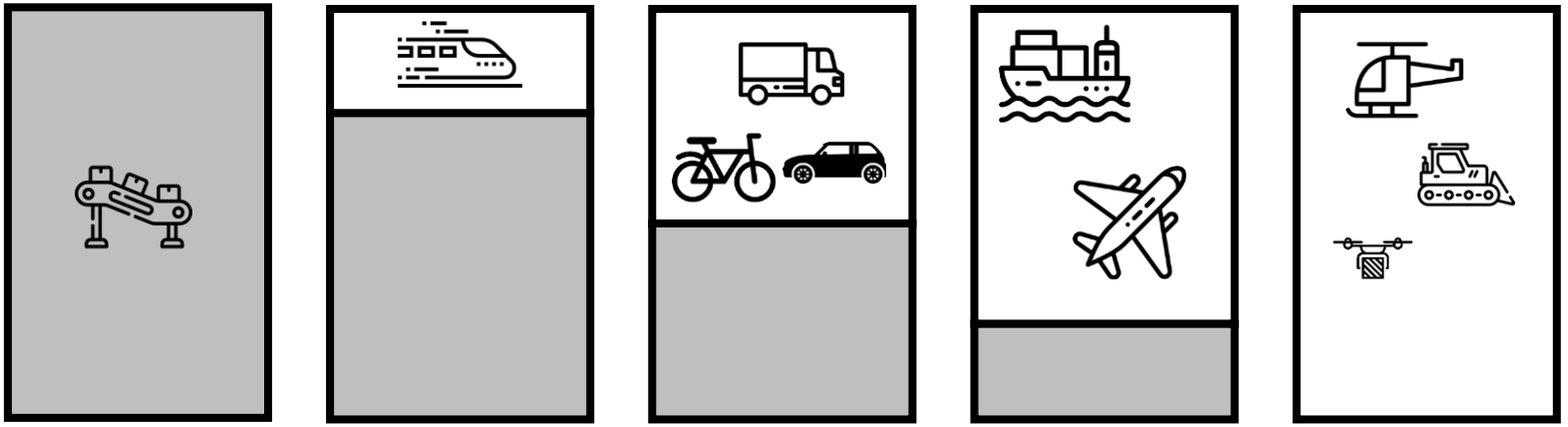
Transport – a structural view



Transport Systems



Vehicle vs Infrastructure



Transport as system of vehicle and (infra)structure

			
	Walking	**Rail**	**Road (Truck)**
Vehicle	-	Train	Truck
Track Infrastructure	Trails	Rail network	Road network
Energy Infrastructure	Food	Electric Grid	Fuel Distribution
Other		Train Station	
Flexibility	High	Low	High
Speed	Very low	High	Medium
Load	Very low	High	medium
Cost Infrastructure	Very low	High	High
Cost Vehicles	none	high	Medium

How has transport to respond to climate change?

1. Mitigate

1. *Decarbonize*

→ Electrify
Engineers like this topic

2. *Avoid and Shift*

→ Serving human needs without or with other modes of transport

mobility researchers like this topic

1. Adapt

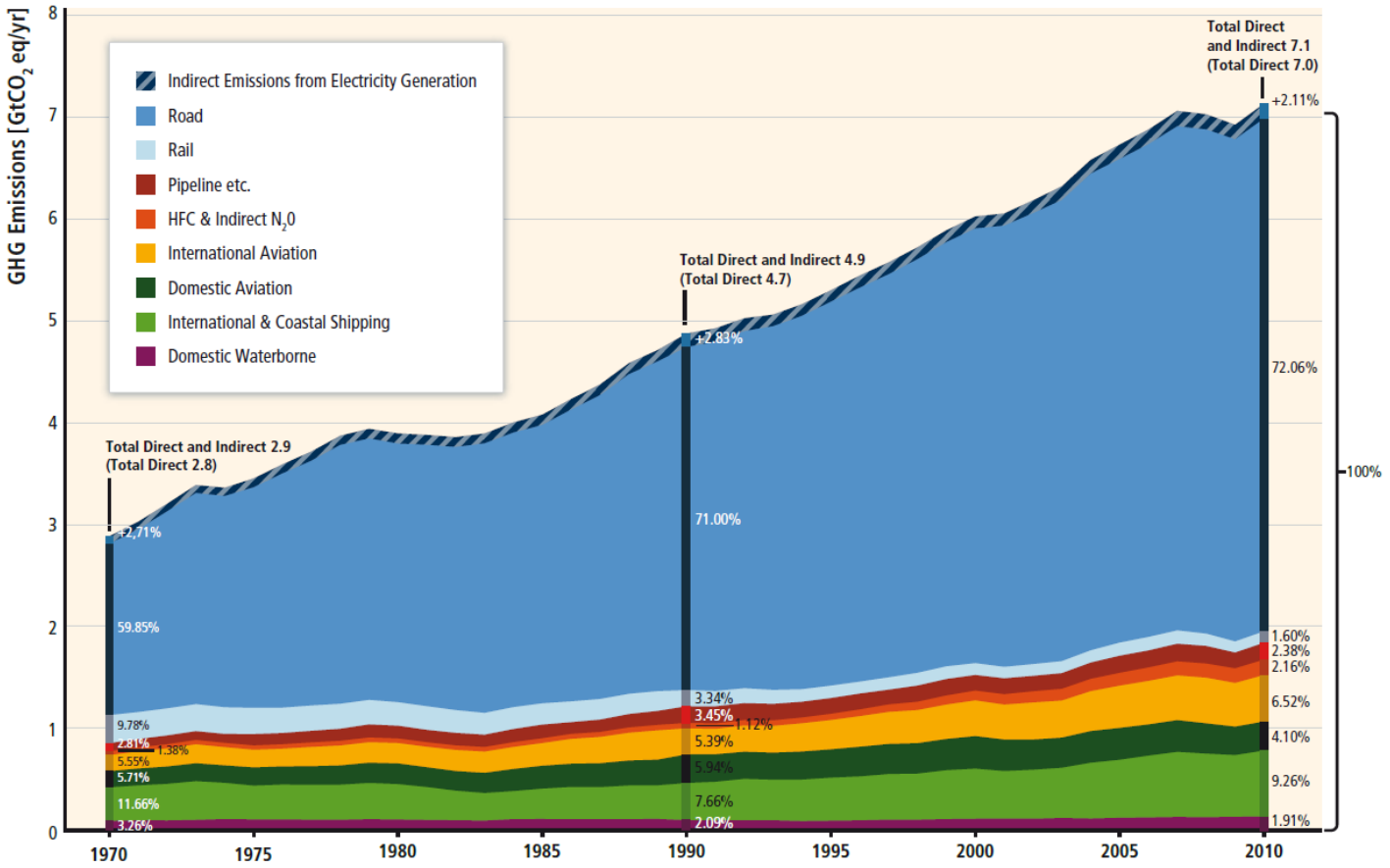
→ Making transport systems resilient (robust, flexible, fixable)

Nobody likes this topic

Mitigation

What means Transport to Climate Change?

Carbon Emissions Transport

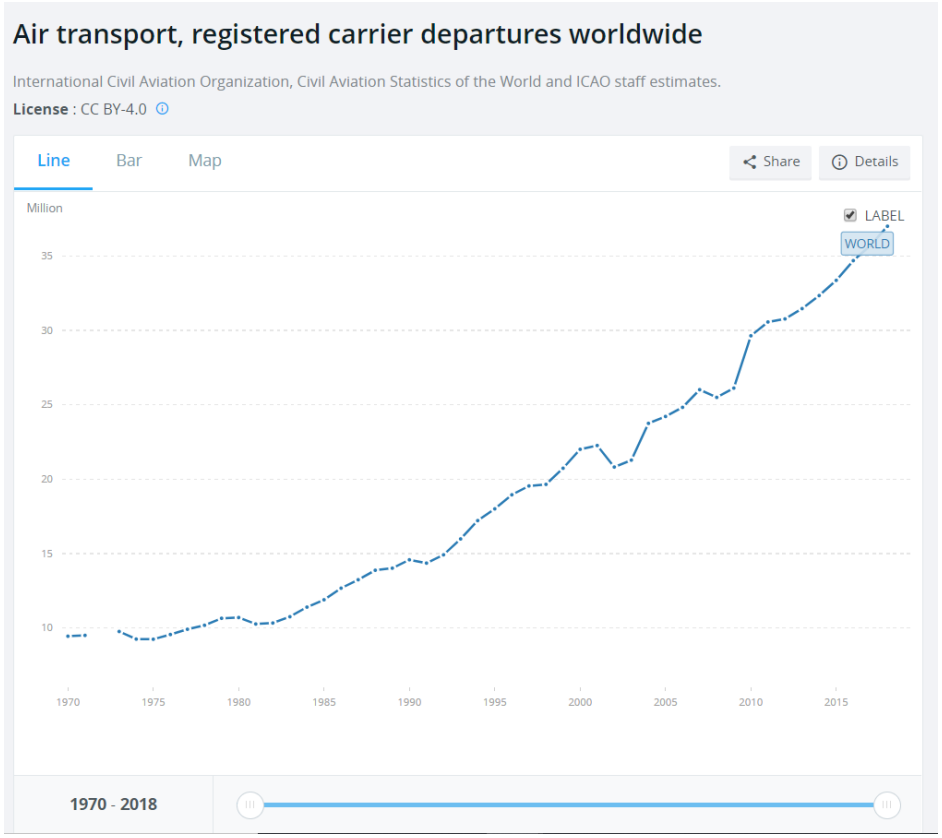


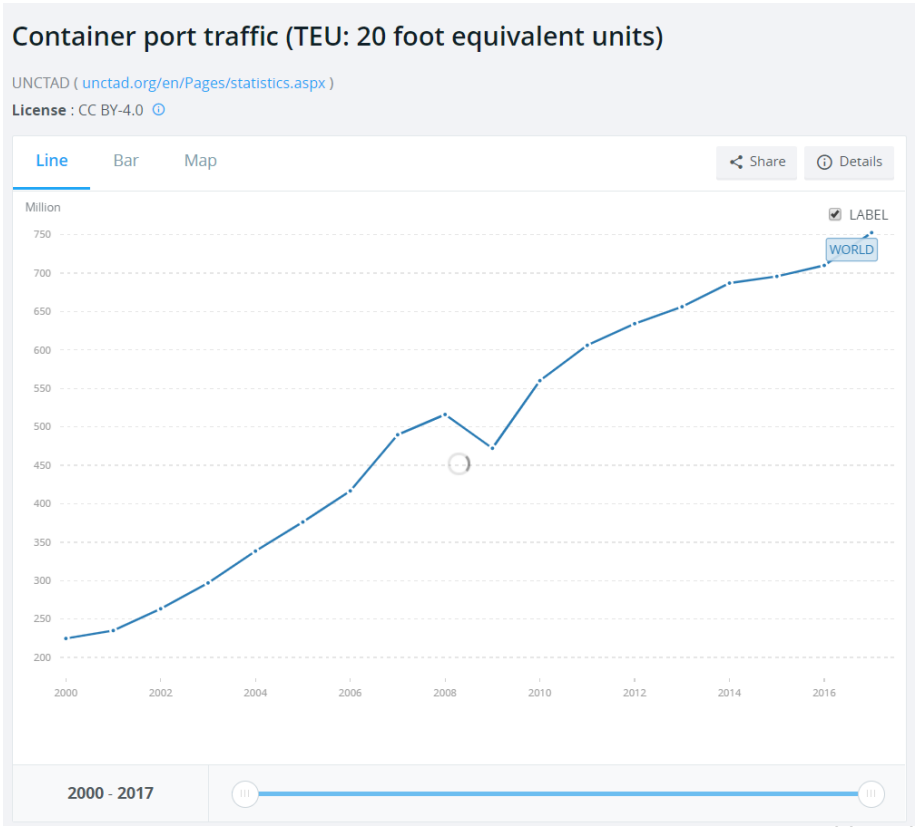
source: IPCC

Figure 8.1 | Direct GHG emissions of the transport sector (shown here by transport mode) rose 250 % from 2.8 Gt CO_2eq worldwide in 1970 to 7.0 Gt CO_2eq in 2010 (IEA, 2012a; JRC/PBL, 2013; see Annex II.8).

Note: Indirect emissions from production of fuels, vehicle manufacturing, infrastructure construction etc. are not included.

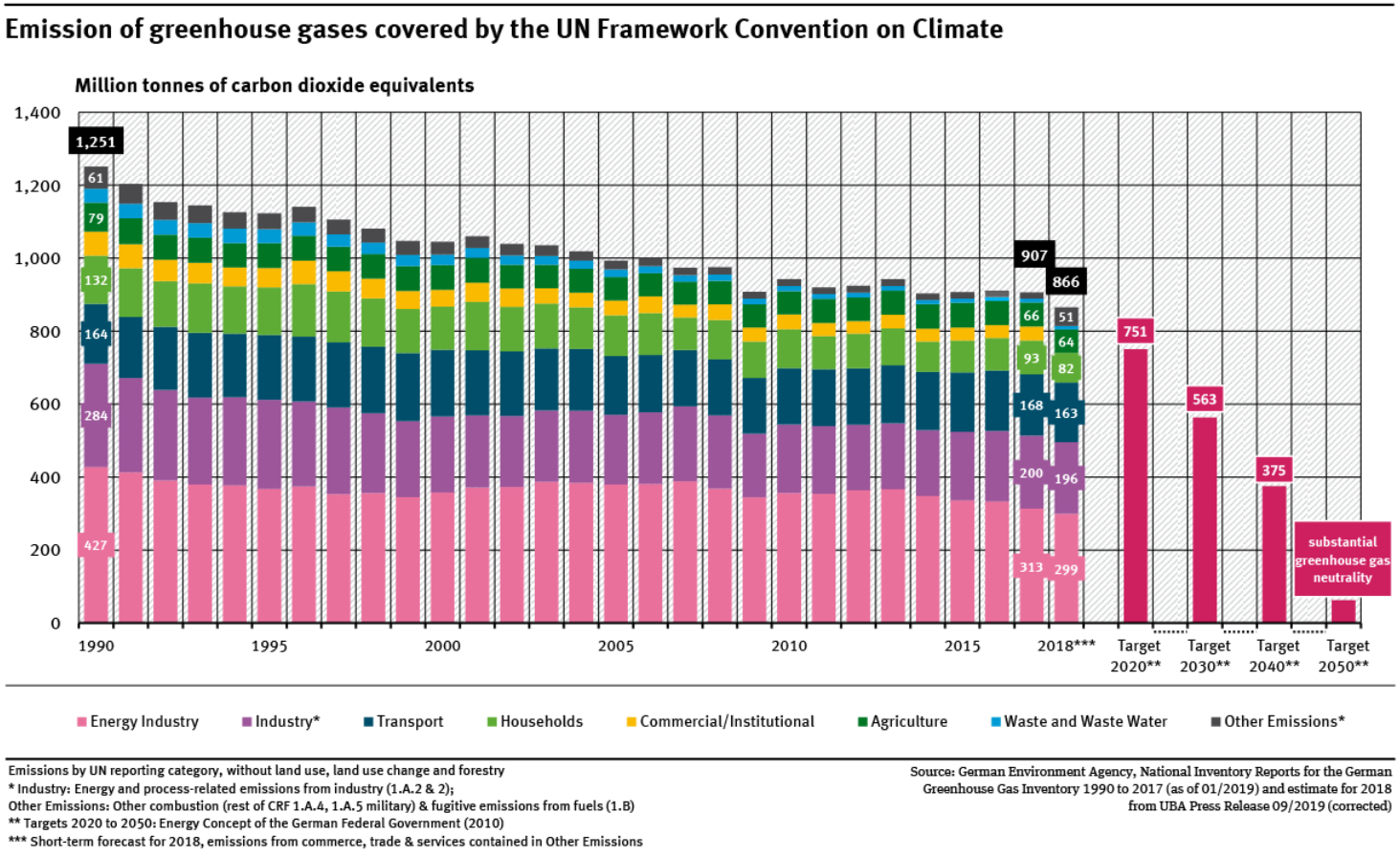
Growth





source: World Bank

GHG Emissions Germany



source: Umweltbundesamt

Transport is oil based

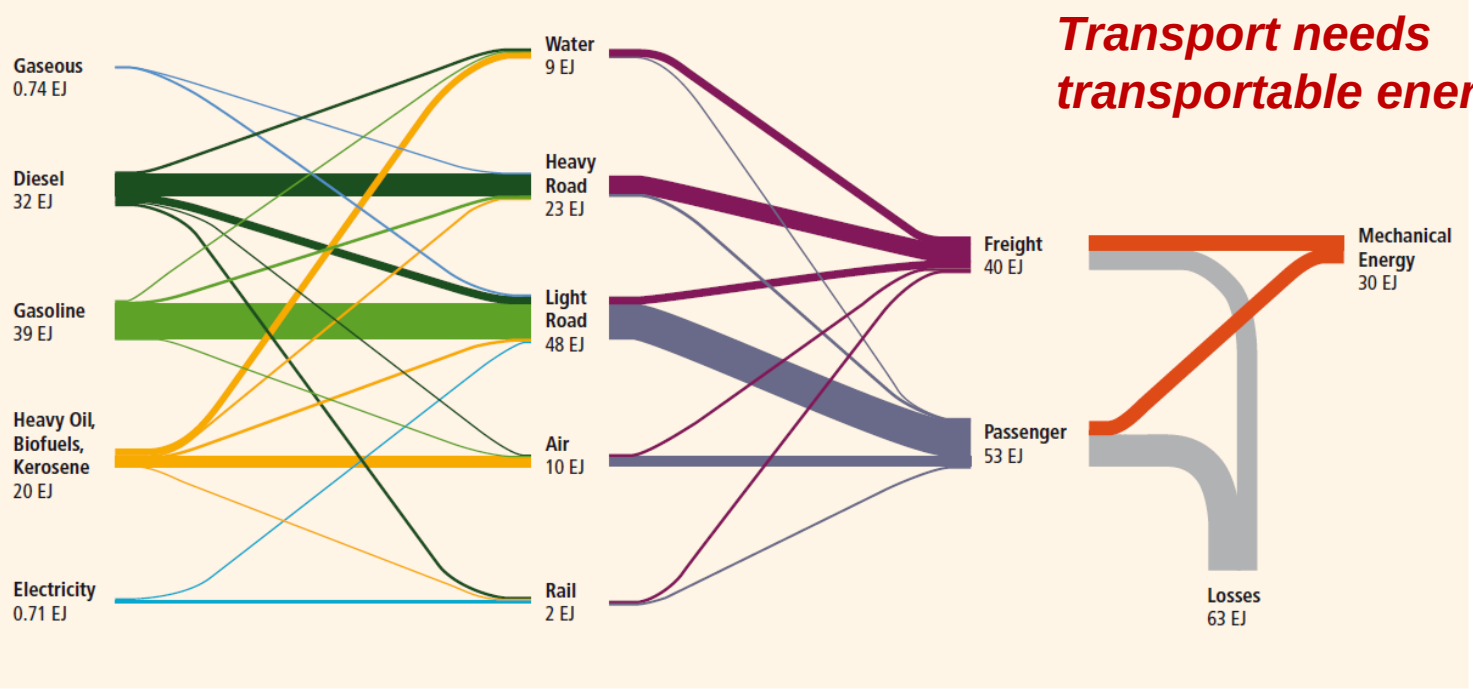
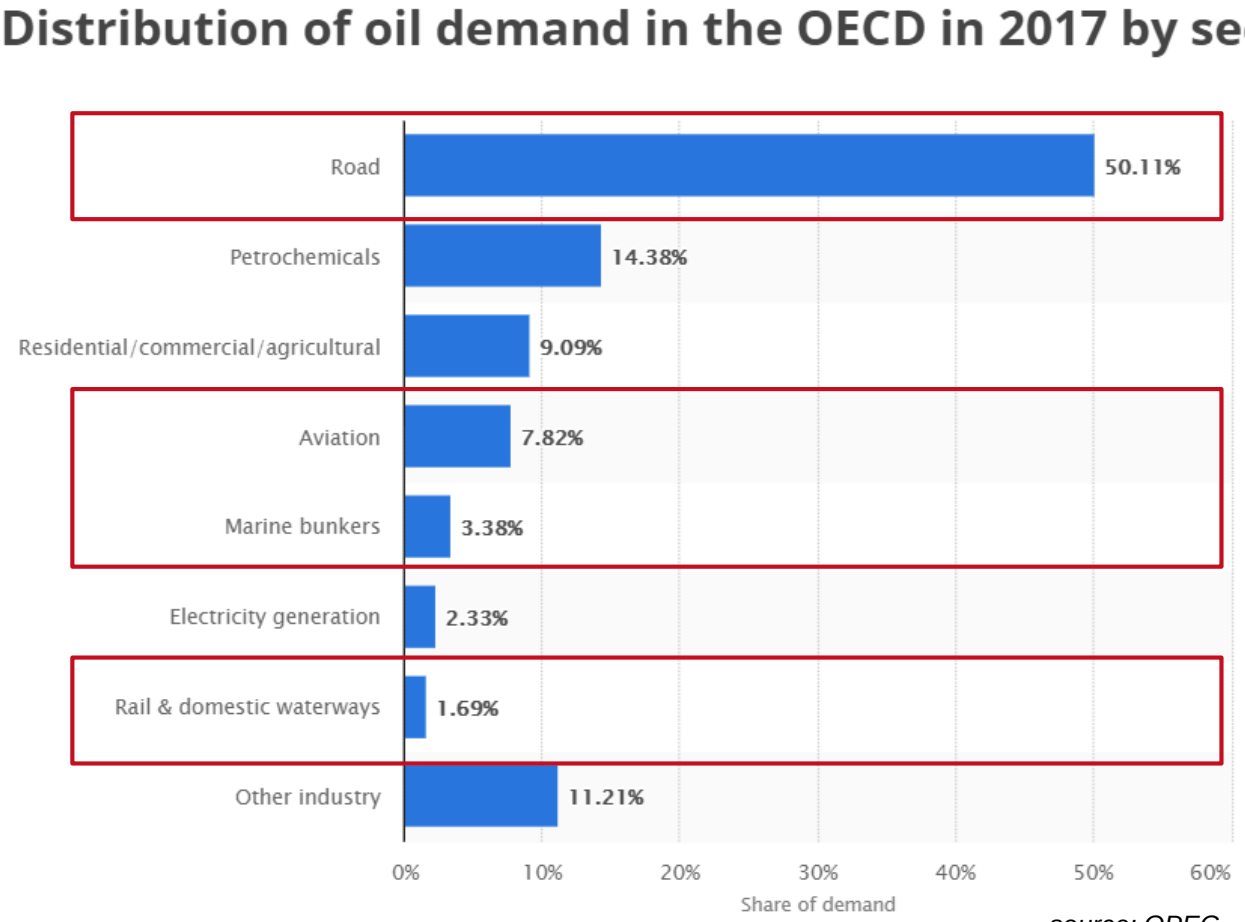
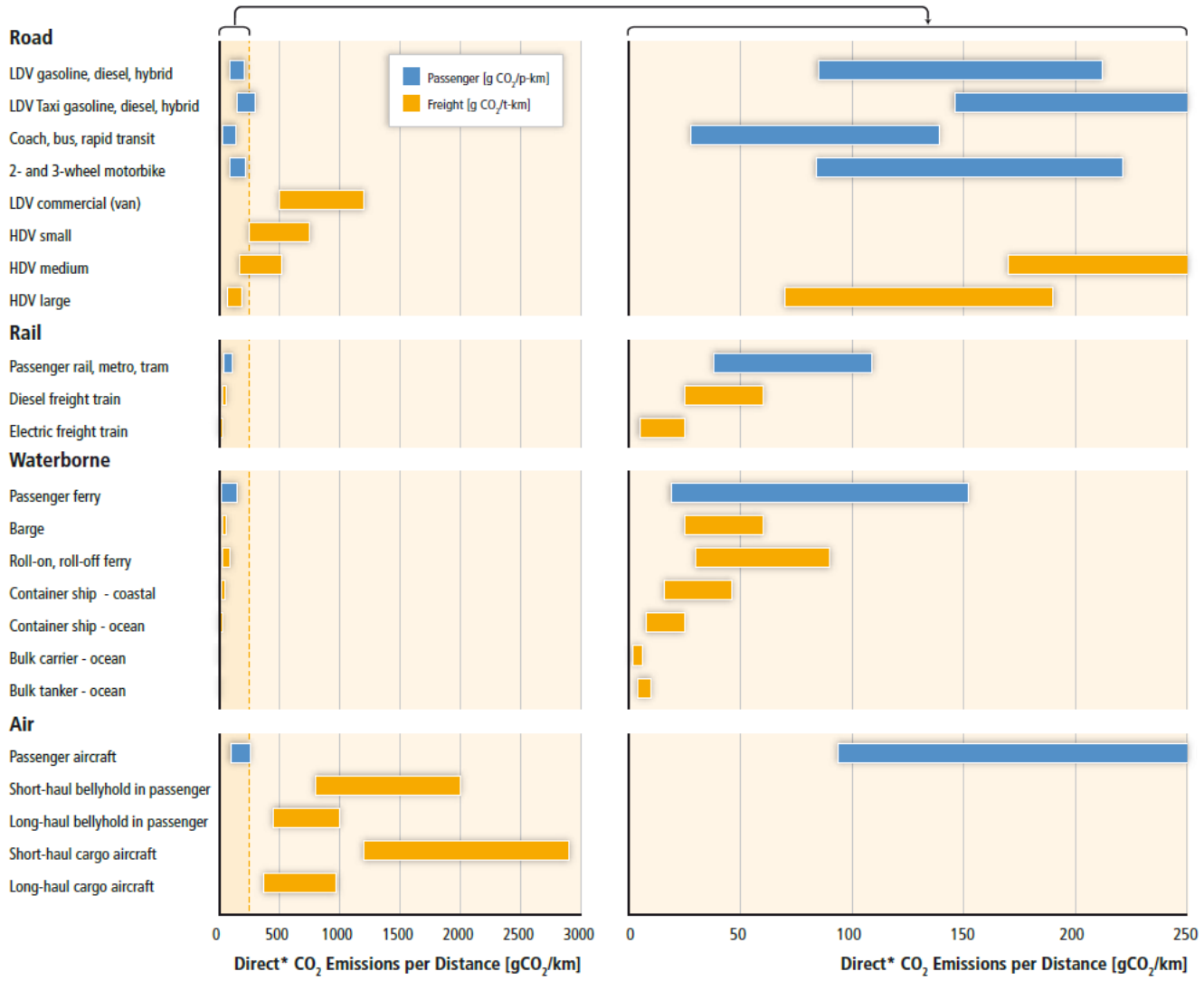


Figure 8.5 | Final energy consumption of fuels by transport sub-sectors in 2009 for freight and passengers, with heat losses at around two thirds of total fuel energy giving an average conversion efficiency of fuel to kinetic energy of around 32 %. Note: Width of lines depicts total energy flows. (IEA, 2012d).

Oil is transport based



source: OPEC



*The ranges only give an indication of direct vehicle fuel emissions. They exclude indirect emissions arising from vehicle manufacture, infrastructure, etc. included in life-cycle analyses except from electricity used for rail.

source: IPCC

Figure 8.6 | Typical ranges of direct CO_2 emissions per passenger kilometre and per tonne-kilometre for freight, for the main transport modes when fuelled by fossil fuels including thermal electricity generation for rail. (ADEME, 2007; US DoT, 2010; Der Boer et al., 2011; NTM, 2012; WBCSD, 2012).

Mitigation Measure I – Technologies

- Electrification
  - Batteries
  - Hydrogen
  - Contact Wire

- Biofuel
- Nuclear

- Autonomous Driving

Technology	Pro	Con
Batteries	• Easy technology (electric motors) • Links to existing infrastructure (power grid)	• Low reach • Ressource usage (rare earths)
Hydrogen	• Medium to high reach • Transportable fuel	• Difficult Technology • Expensive
Contact Wire	• Links to existing infrastructure (power grid) • Well known technology	• Initial Investment • Maintenance • Not innovativ
Biofuels	• Compatible with existing technology (motors) and infrastructure	• Not reallycarbon neutral • Crowding out of food crops
Nuclear	• Very (!) high reach • Existing Technology, in use	• All what is wrong with nuclear in general

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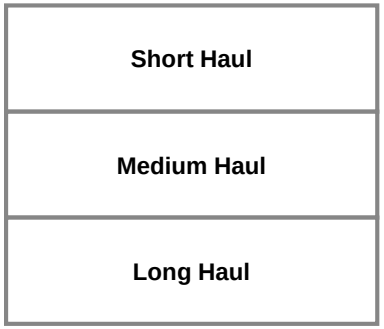

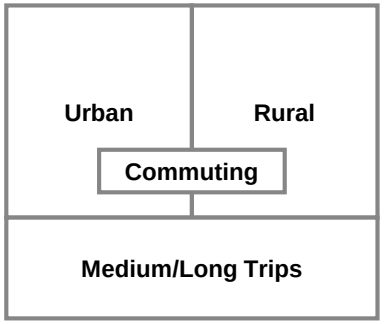

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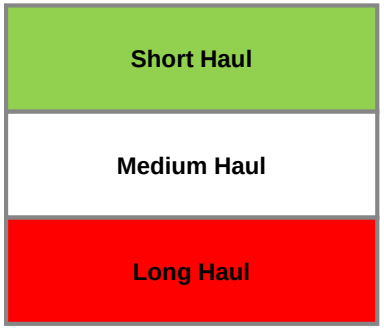

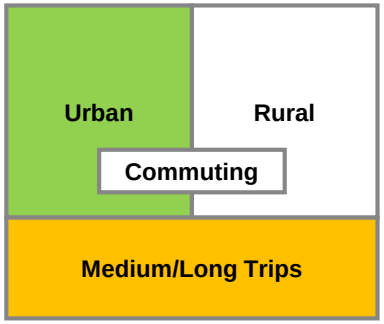

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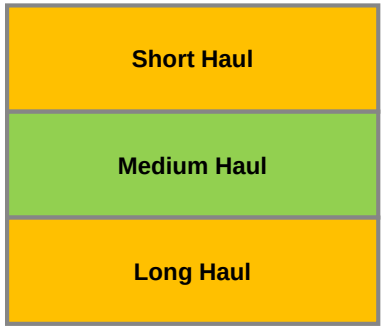

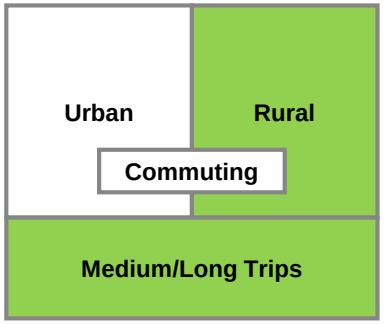

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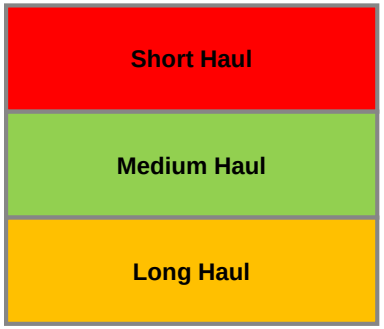

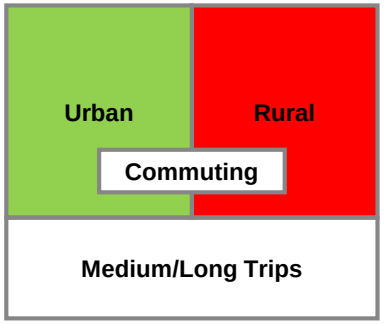

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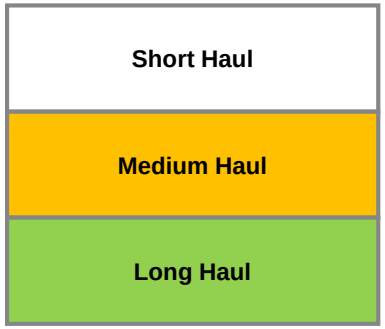

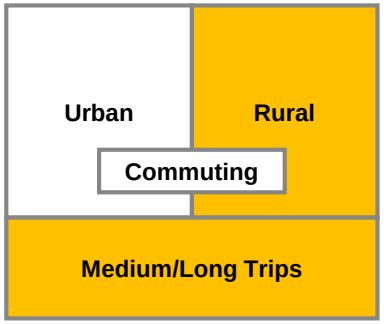

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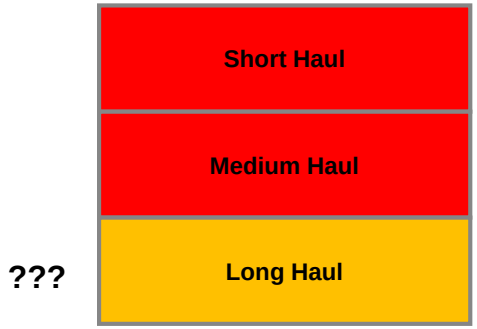
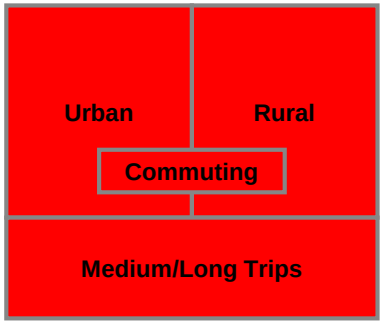
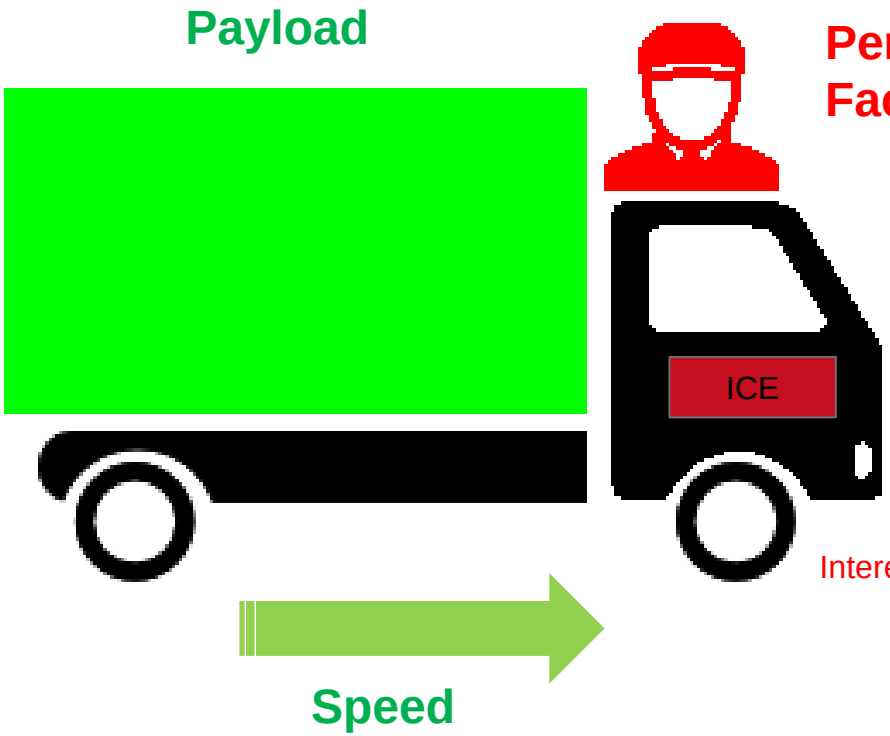




Truck

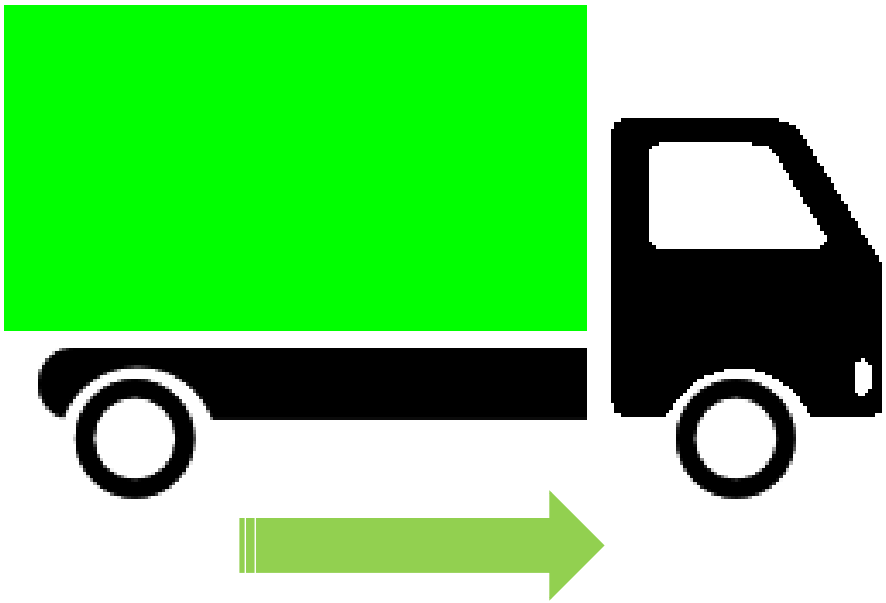
How the freight industry sees it



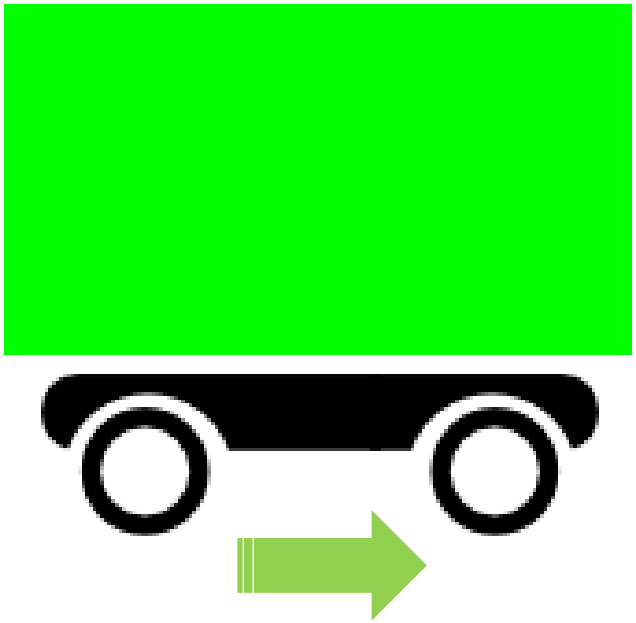
Personell costs
Factor of unreliability

Interest/depreciation

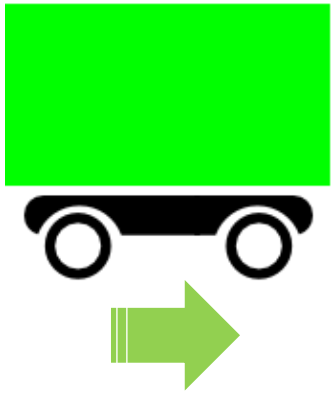
Autonomous Driving



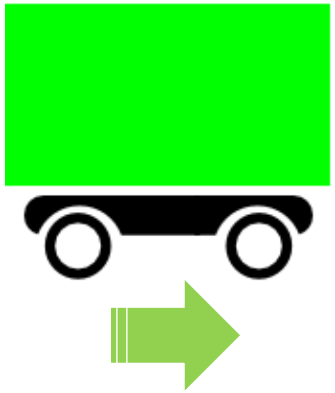
Autonomous Driving



Electrifictaion --> Miniaturisation



Miniaturisation



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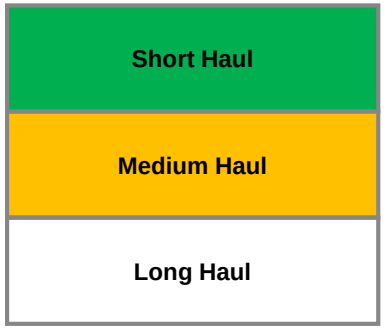
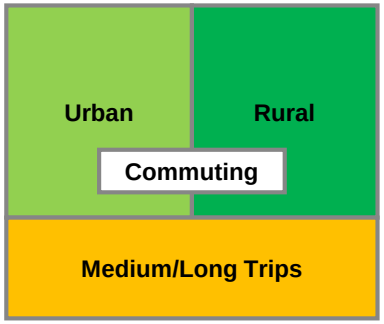




Unsolved Issues

Maritime Transport

- Pro: very efficient
- Very high reach needed
- Very little infrastructure
- Ships are currently waste burners
- High energy density

- Batteries: not enough capacity
- Hydrogen: might work,

- Large international shipping as the last refuge for nuclear?

Air Transport

- Pro: infrastructure light and flexible

- High reach, low load

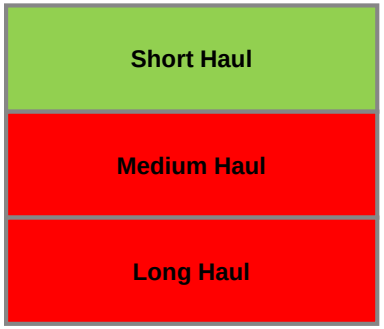
- Batteries: not realistic for long haul (except air ships)
- Hydrogen: dangerous in high altitudes

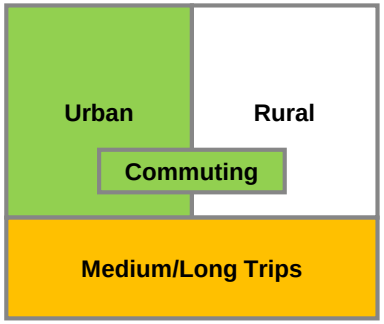
- Current approach: Biofuel and reduce

Better Solutions needed!

Mitigation Measures II -- Policies

- **Modal Shift**
- Avoiding





Mitigation Measures II -- Policies

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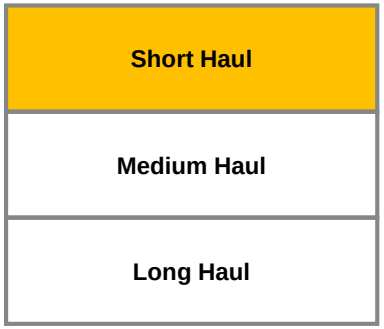
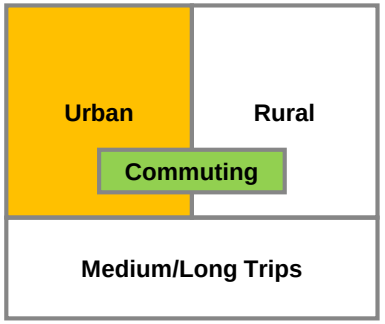
- **Avoiding**





Mobility (Passenger Transport)

Urban

- Almost no real mobility problems
- Relatively good provision of public transport
- Overabundance of new mobility offers
- Attractive B2C market

- **Solutions known, issue: implementation**

- High interest of mobility research

Rural

- Large and increasing problems
- Poor provision of services
- Almost no new mobility solution providers present
- Unattractive market, difficult business models

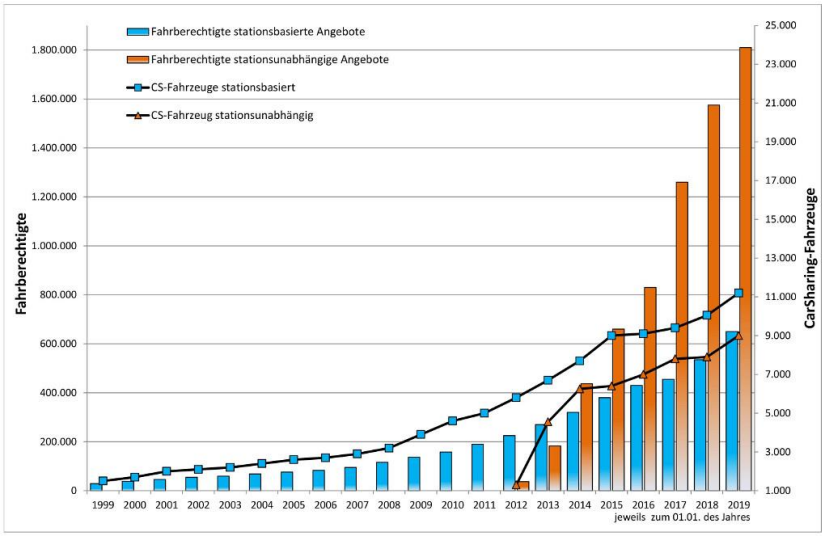
- **Solutions unknown, need for innovation**

- Low interest of mobility research

Urban Transport - end of the age of cars

- Public Transport
- Public Transport
- Public Transport
- Large ‚Container' sizes
- Getting cars out of the city
- People driven Transport (Walking, Biking)
- Electrification
- Some autonomous shuttles
- Avoid and shift

CarSharing in Germany



source: Bundesverband Car Sharing

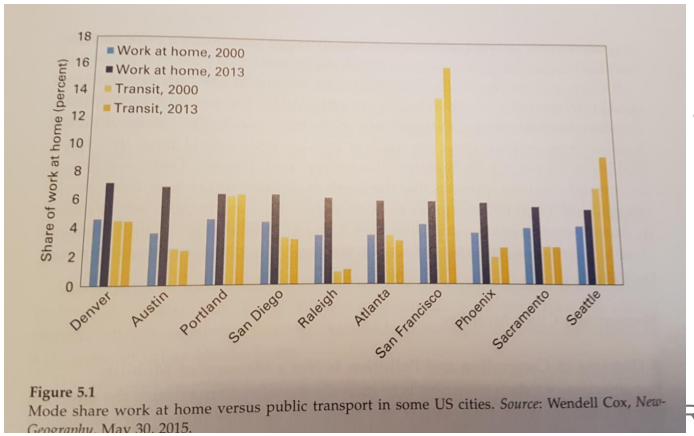
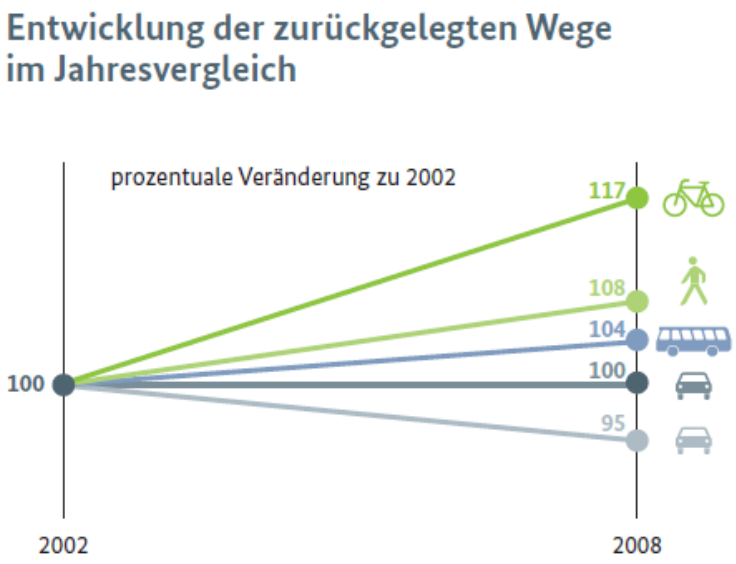


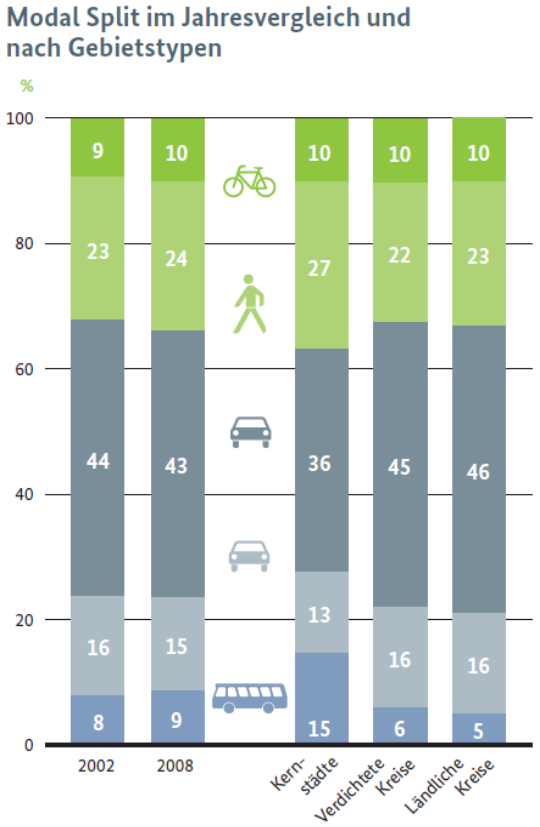
Figure 5.1
Mode share work at home versus public transport in some US cities. *Source*: Wendell Cox, *New-Geography*, May 30, 2015.

source: A. Bertaud, Order without Design, 2018

Urban Transport – Modal Shift



Angaben für 2008. Quelle: MiD 2008.



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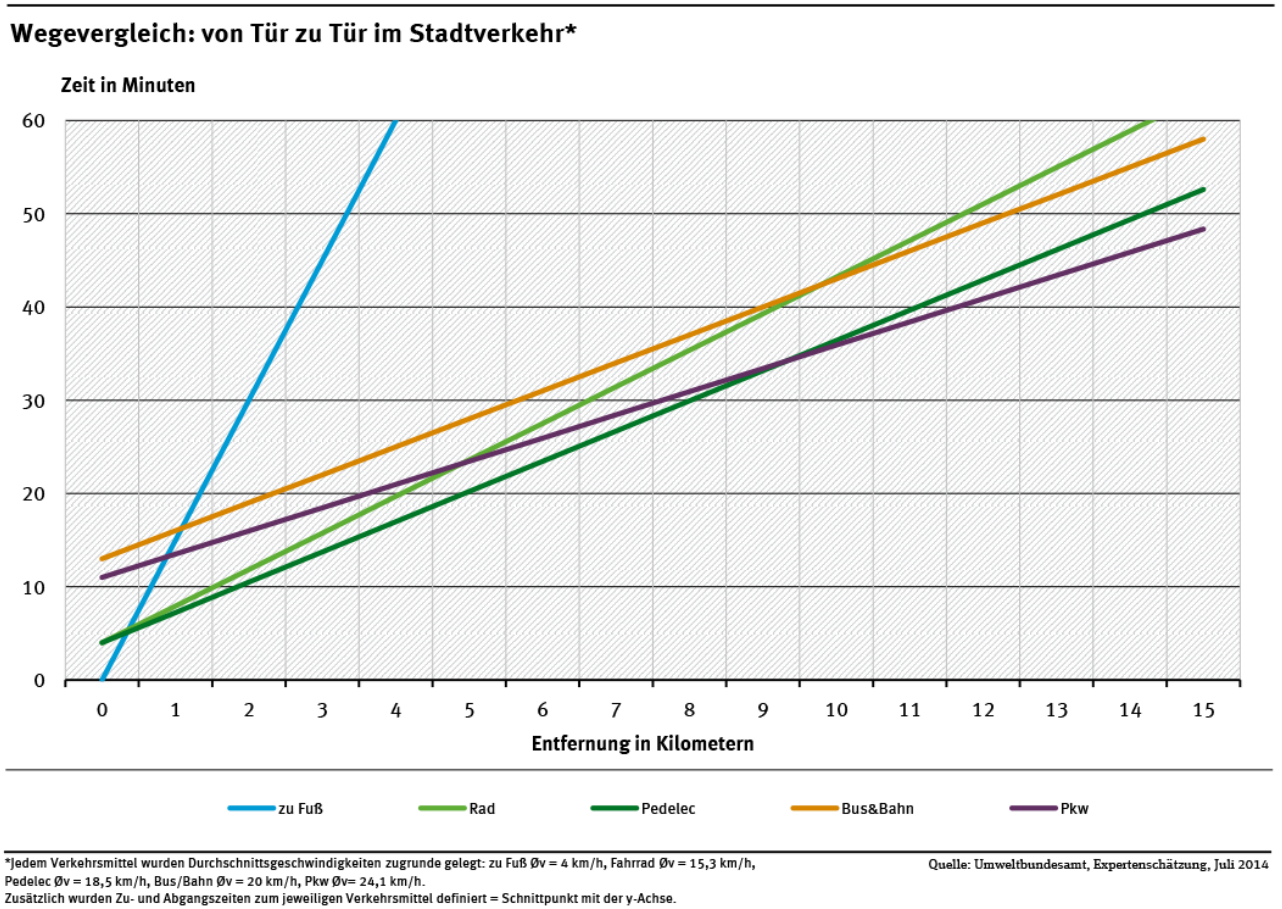
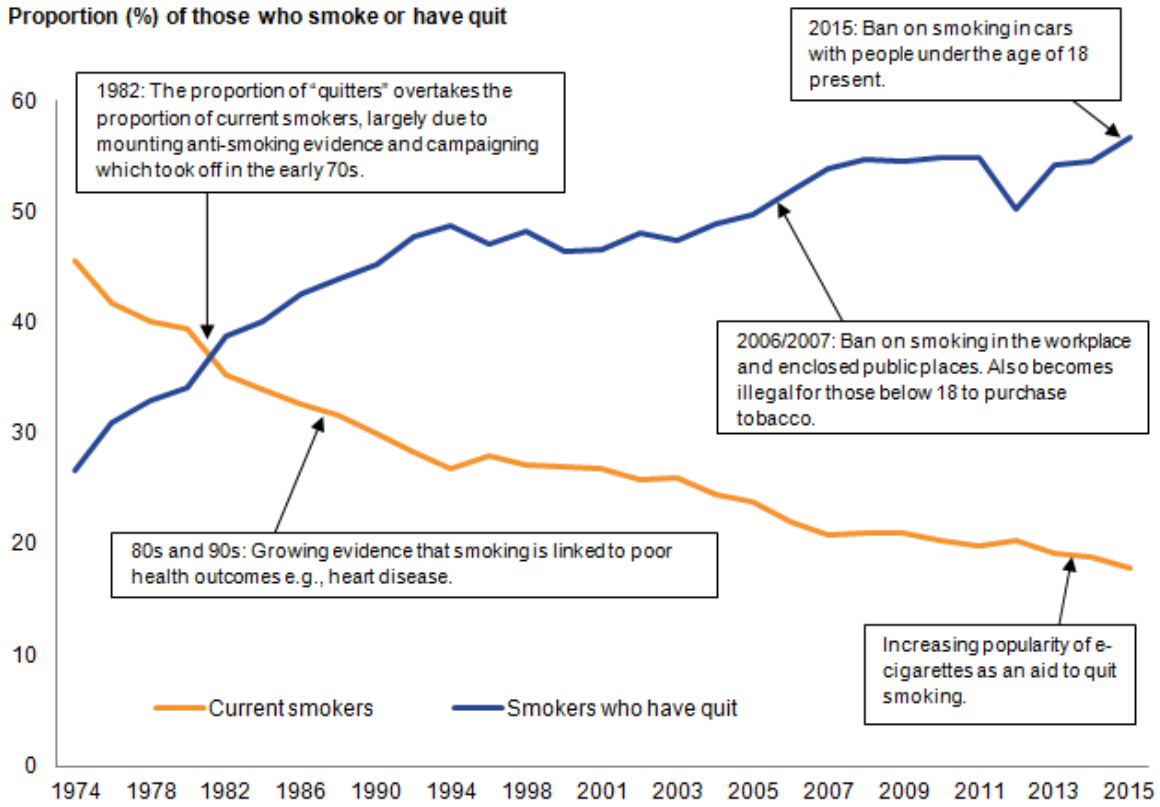
Urban Transport – Bike performance



source: Umweltbundesamt

„The Car won‘t go away.“ Remember Smoking?

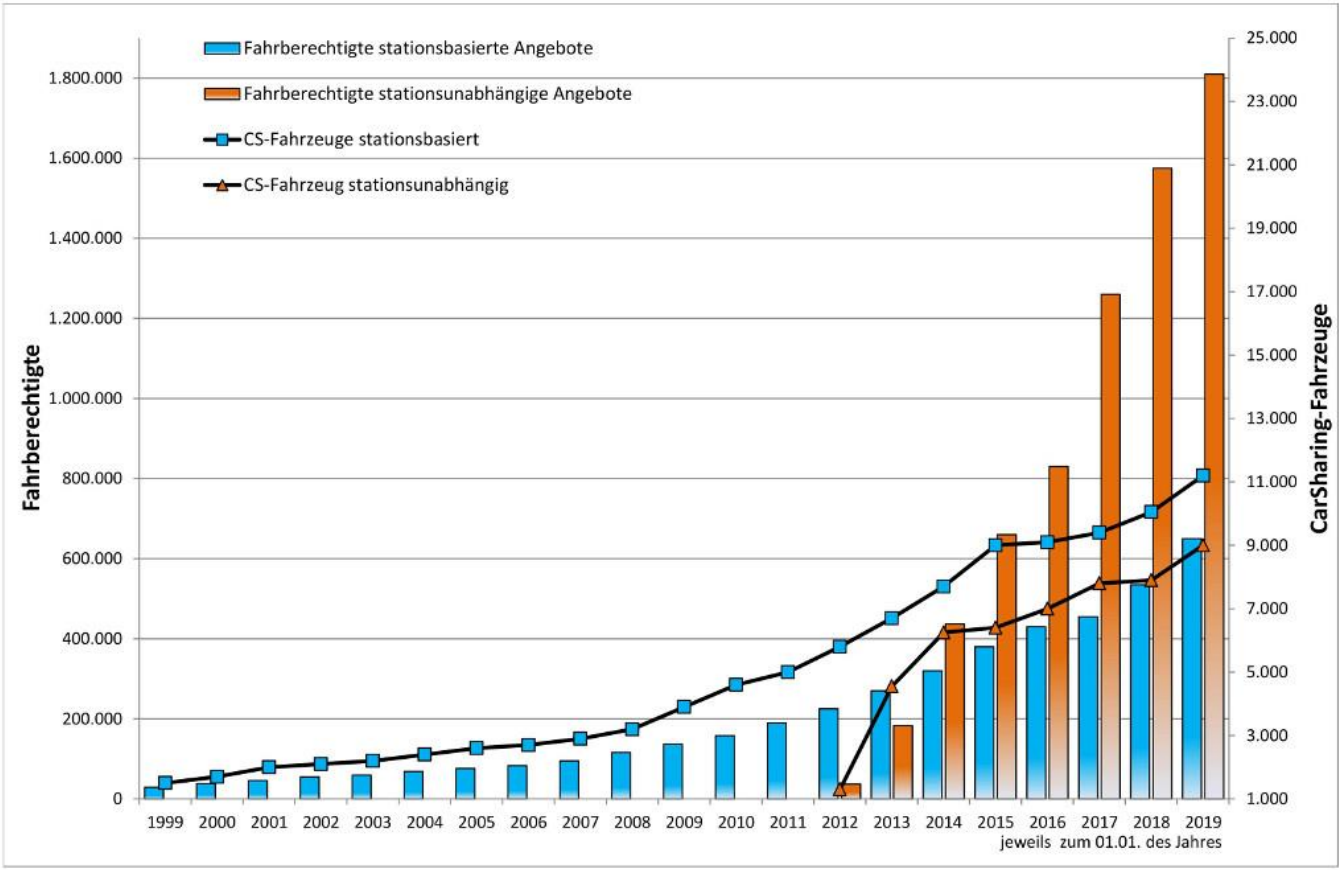
Smokers in UK



source: UK Statistics Office

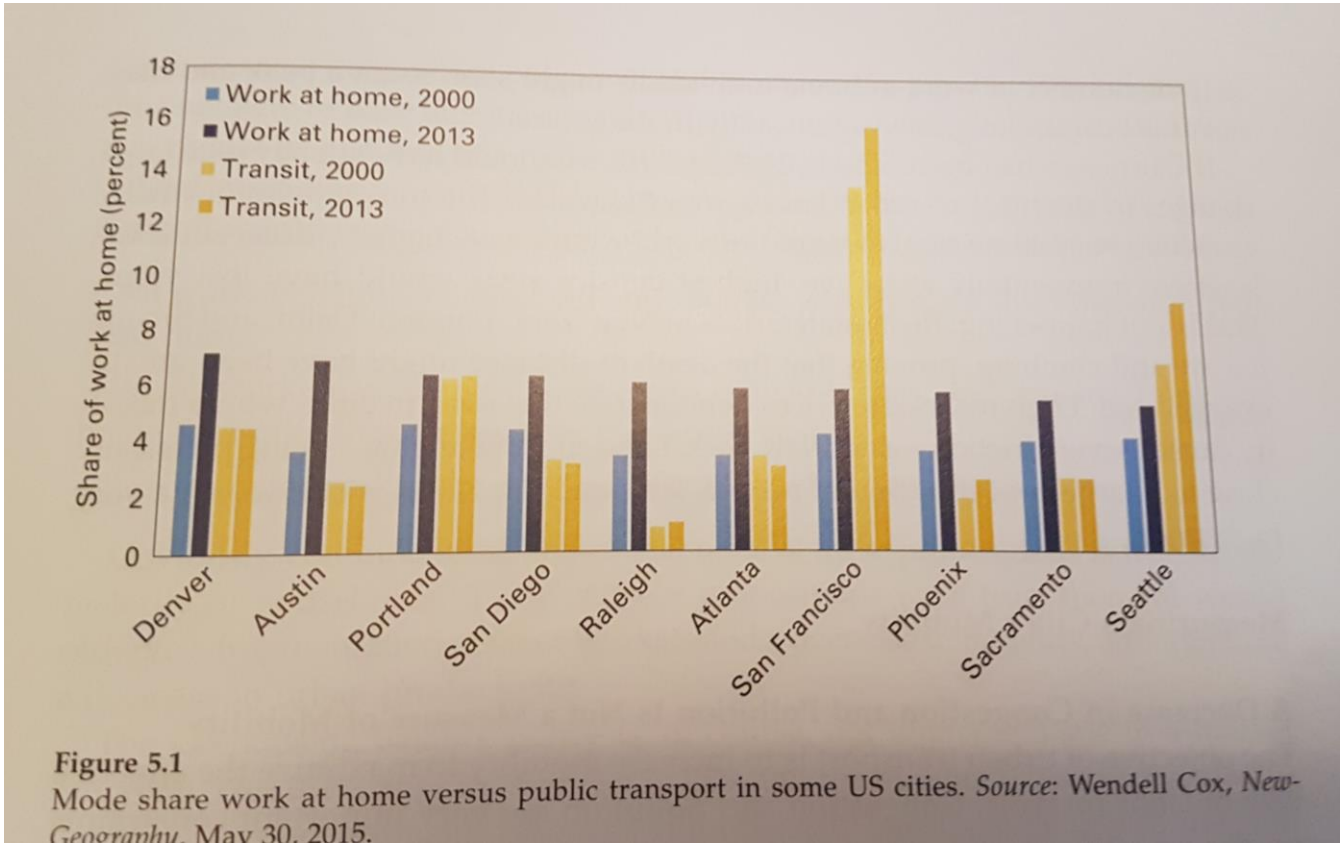
Urban Transport – „Sharing“

CarSharing in Germany



source: Bundesverband Car Shring

Urban Mobility – Avoiding the Commute



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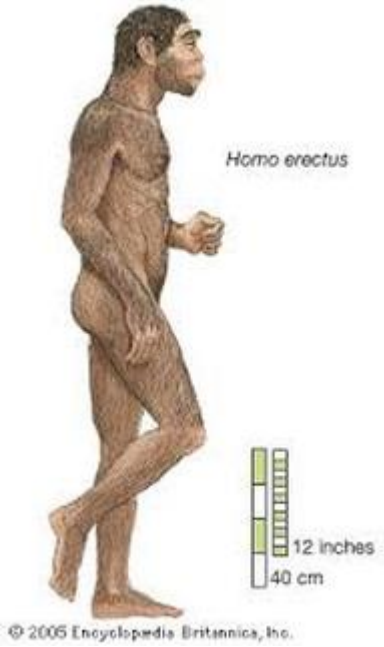
Last Mile – mobility



Why care?

Rural Mobility – Transport Poverty

An individual is **transport poor** if, in order to satisfy their daily basic activity needs, at least one of the following conditions apply:

Availability:	**Accessibility:**	**Affordability:**	**Time budget:**	**Adequacy:**
No suitable transport option available	Transport options do not reach destinations and opportunities	High cost burden	Excessive amount of time in travel	Travel conditions are dangerous, unsafe or unhealthy for the individual.

source: HiReach Project

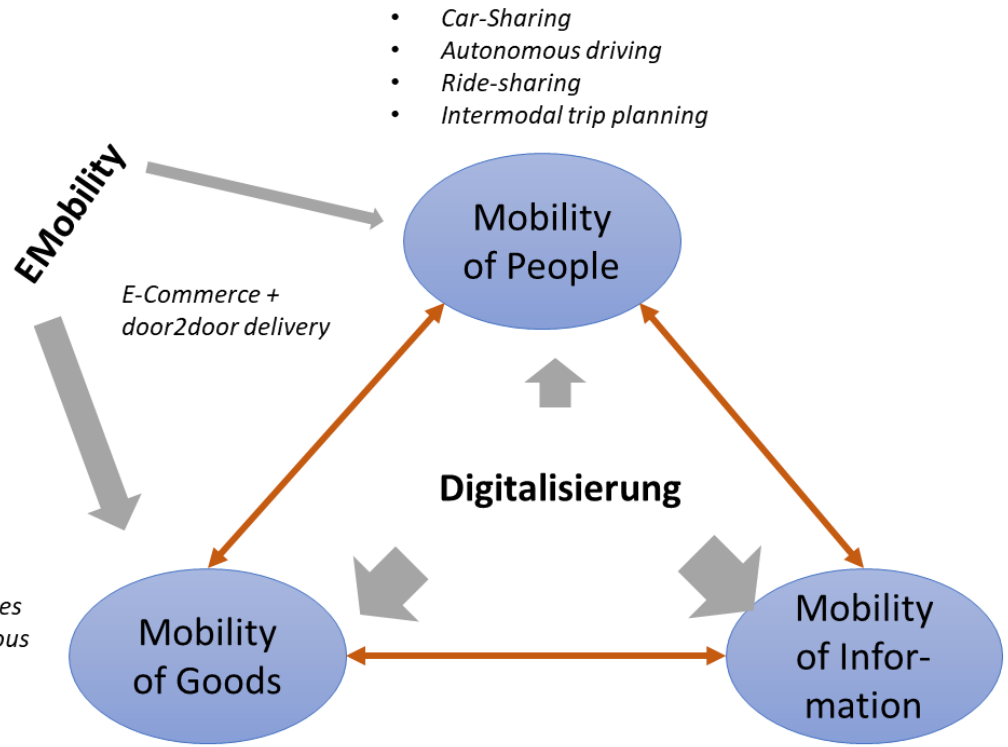
Rural Mobility – Transport Poverty

Depending on the needs of different social groups, some conditions are more important than others

SOCIAL GROUPS	AVAILABILITY	ACCESSIBILITY	AFFORDABILITY	TIME-BUDGET	ADEQUACY
Low income and unemployed	✓	✓	✓	✓	
Elderly people		✓			✓
People with reduced mobility		✓		✓	✓
Women	✓	✓		✓	✓
Migrants and ethnic minorities			✓	✓	✓
Children and young people	✓		✓		✓
People living in rural and deprived areas	✓	✓	✓	✓	

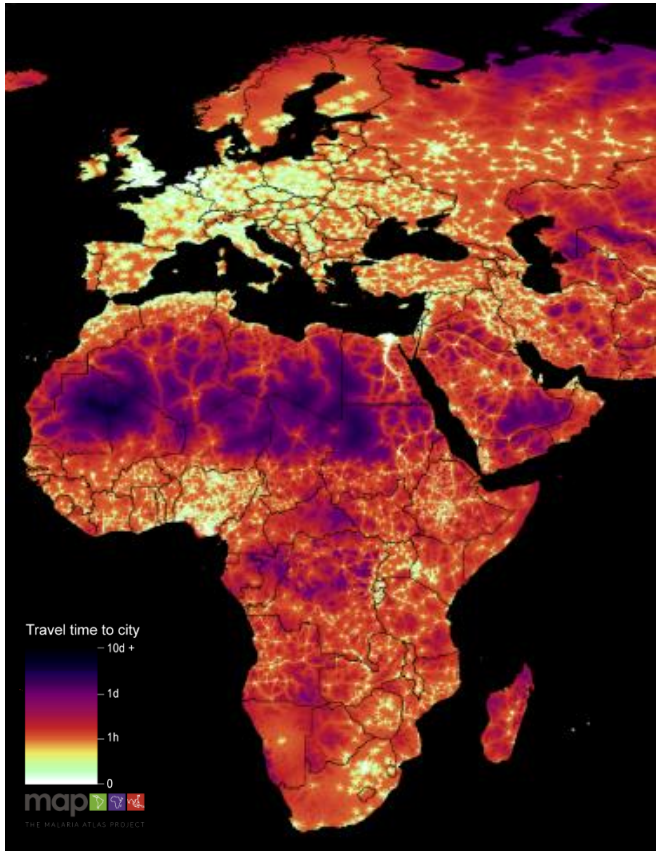
source: HiReach Project

Rural Mobility



The Greenfield: Africa

- Only 34% of the inhabitants of southern Africa have street access.



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2015
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Table 1.1 Density of Paved Roads in Sub-Saharan Africa, Compared with Other Low-Income Countries

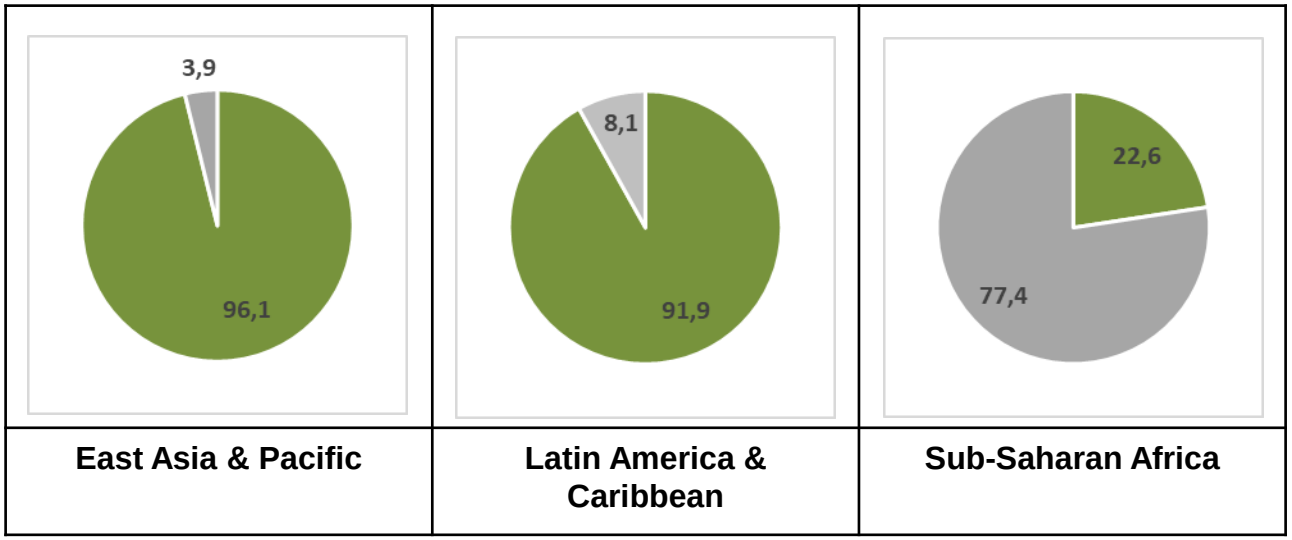
	Sub-Saharan Africa low-income countries	Other low-income countries
Density by area (km/1,000 km²)	10.7	37.3
Density by population (km/1,000 population)	269.1	700.7
Density by GDP per capita (km/US$ billion)	663.1	1,210.0

Source: Carruthers, Krishnamani, and Murray 2008.

Energy Poverty

- Energy Poverty: keine Anbindung ans Energienetz behindert die wirtschaftliche Entwicklung ländlicher Räume (und GHG-Emissionen durch Dieselgeneratoren).

Access to electricity, rural (% of rural population)



source: Own Design, Data: World Bank

Adaptation

What means Climate Change for Transport?

What Means Climate Change for Transport

Climate Change means…

Our world is and will be constantly and fast changing
→ we need flexible, light-weight systems, easy to adapt and to rearrange

We will have to cope with more (destructive) weather events and other natural hazards
→ We need resilient systems, either cheap and easy to replace or robust and easy to repair

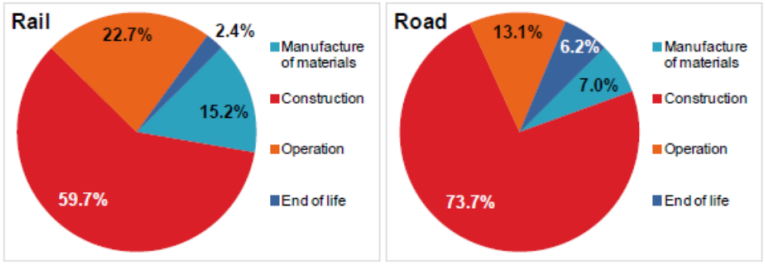
The issues with infrastructure

- Not carbon neutral themselves
- Expensive
- Long Term Investment: depreciation cycles of 50 years
- → Induce high path-dependency
- Induce Traffic

GHG Emissions

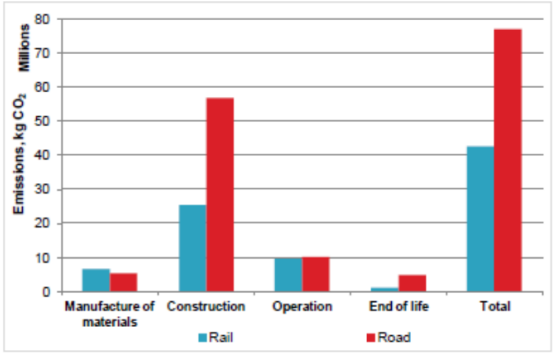
GHG Emissions Infrastructure

Figure 3.17: Total CO_2 emissions for rail and road infrastructure (%)



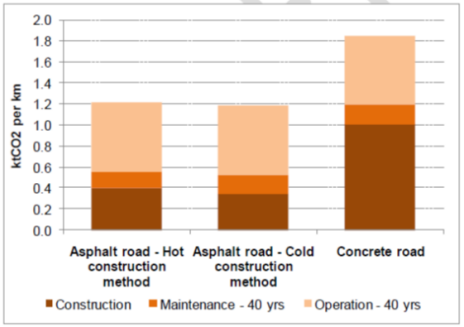
Source: Adapted from Claro (2010)

Figure 3.16: Total CO_2 emissions for rail and road infrastructure (kg CO_2)



Source: Adapted from Claro (2010)

Figure 3.1 GHG emissions during 40 years of service life of a 13 m wide road in Sweden (adapted from Stripple, 2001).



Source: EU-Transport-GHG-2050

Table 1. Infrastructure life-cycle emissions (tCO_{2e} km^{-1} y^{-1}) of the road construction.

Author	Country/Year	Lifespan (y)	tCO_{2e} km^{-1} y^{-1}
1. Park	Korea/2003	20	447
2. Carlo	Spain/2010	50	160
3. Loijos	USA (Massachusettes)/2011	40	10–162

Table 2. tCO_{2e} km^{-1} of road construction of some studies.

Author	Country/Year	Lifespan (y)	tCO_{2e} km^{-1} y^{-1}
1. Mroueh	Filand/2000	50	6–12
2. Stripple	Sweden/2001	40	50–62.5
3. Athena Institute	Canada/2006	50	1–25.3
4. Birgisdottir	Denmark/2006	100	26.7
5. SUSCON	Greece/2006	50	18.8
6. Milachowski *et al.*	Germany/2011	30	56.5
7. Barandica *et al.*	Spain/2012	50	177–1006
8. Huang	UK India/2012	25	35.9–385

Source: Dimoula/Kehagia/Tsakalides 2016

Source:

Emissions Rail Infrastructure

Mode/component	Emissions ($gCO_2eq/p\text{-}km$)	Reference	Comment
Swedish high-speed rail plans for Europabanan infrastructure	2.7	Amos et al., 2010; Åkerman, 2011	At 25 million passengers per year
Vehicle construction and maintenance emissions; Swedish high-speed rail	1.0	Åkerman, 2011	Over full lifetime of high-speed rail vehicles
Inter-city express (ICE) system study (Germany and surrounds)	9.7	Von Rozycki et al., 2003	About half total emissions arise from infrastructure including non-high-speed stretches
High-speed rail infrastructure (Europe)	3.1–10.9	Tuchschmid, 2009	Low emission value for 90 trains per track per day, high emission value for 25. Current EU network is at 6.3 g/p-km
US high-speed rail plans	3.2 g/p-km	Chang and Kendall, 2011	This 725 km line will emit 2.4 $MtCO_2eq/yr$

Note: Since LCA assumptions vary, the data can only be taken as indicative and not compared directly.

source: IPCC

Costs

- High Investment costs
- Long investment cycles
- Follow-up maintenance
- → strong path dependency

source: DeStatis, ViZ

Total Value German Transport Infrastructure: 773 billion EUR

Source: destatis

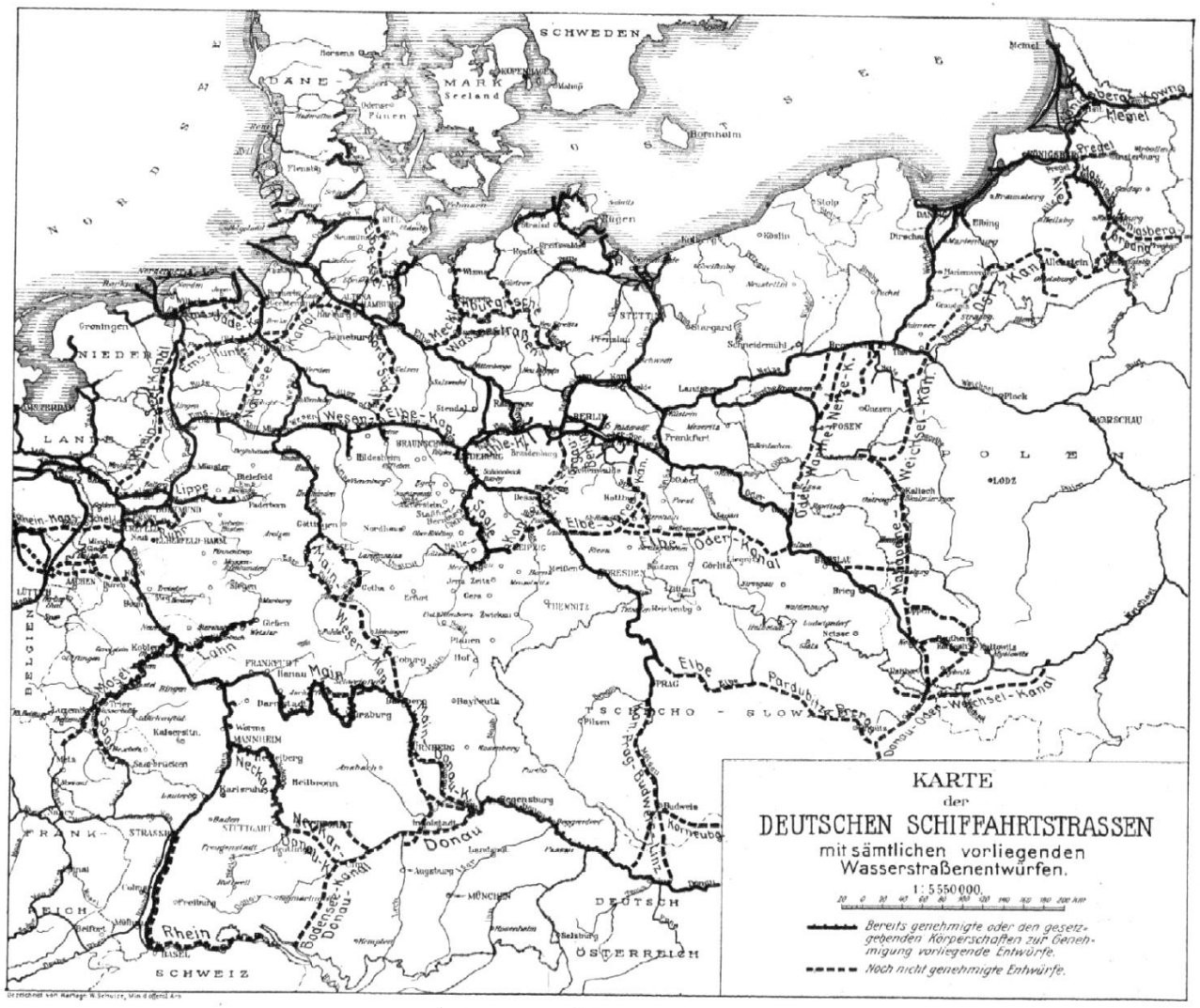
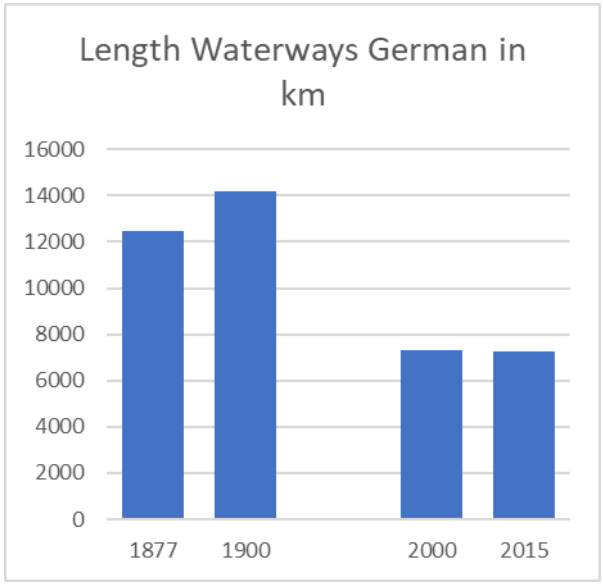


Abb. 2.

German Waterways 1920



source: Own Design, Data: ViZ, Destatis

German Waterways 2019

„Alle schiffbaren Wasserstrassen, Seen, Kanäle und Flüsse in Deutschland“ http://www.water-ways.net/d/info/deutschland/

… and its age

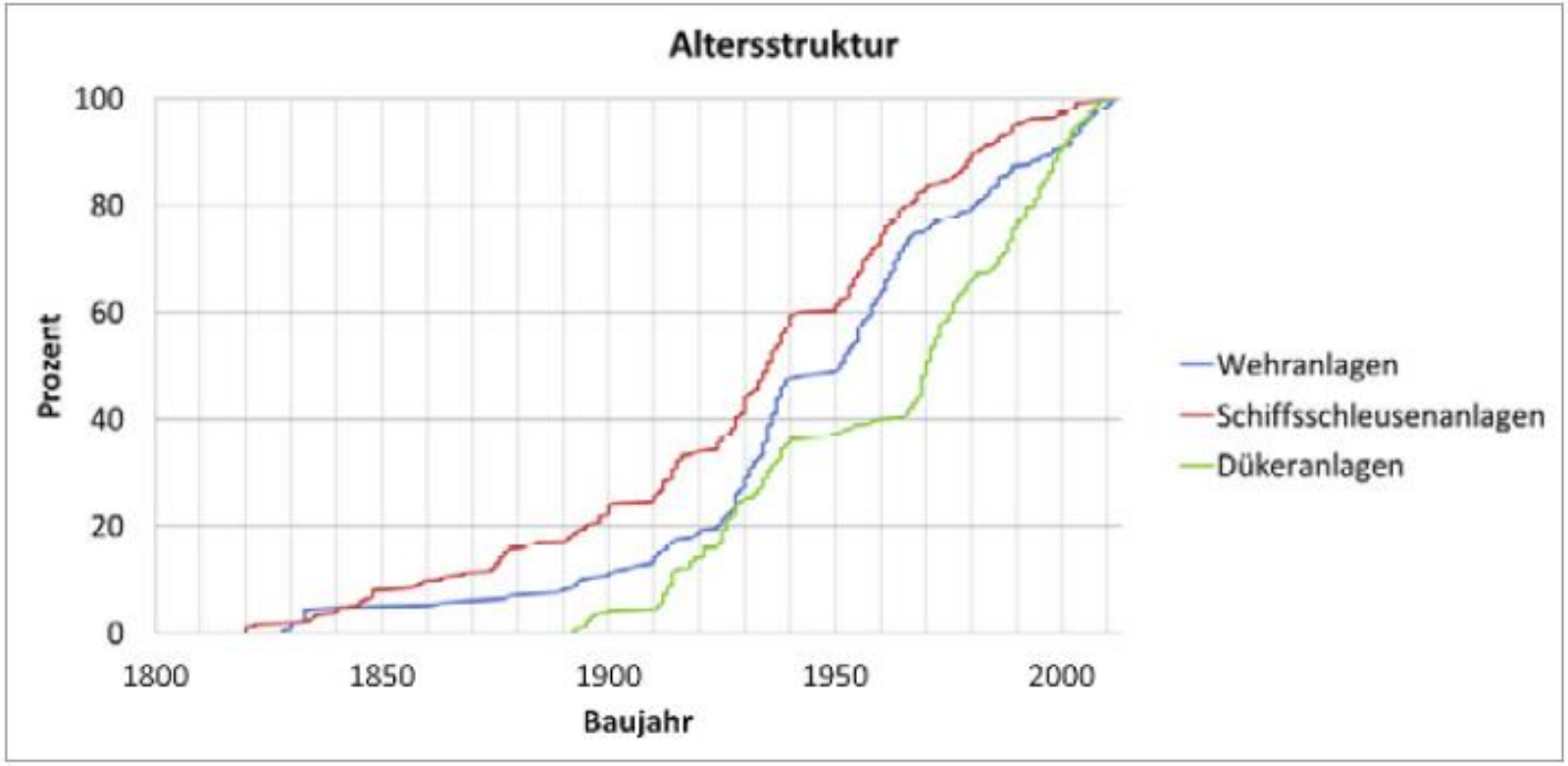


Abbildung 11: Altersstruktur ausgewählter Anlagen an den Bundeswasserstraßen

BVWP2030, 2016, S.31

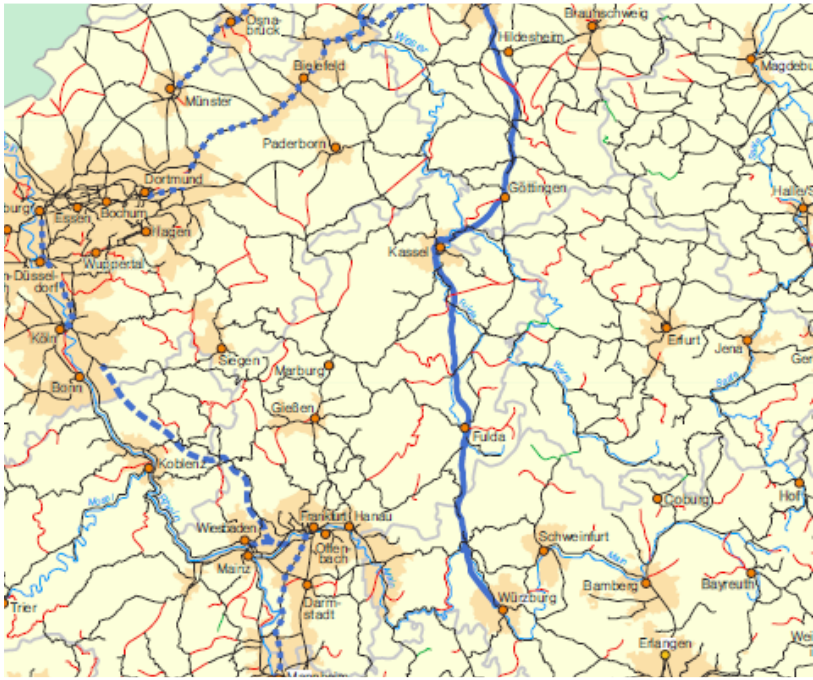
Technische Universität Berlin

Railroad in Germany 1950

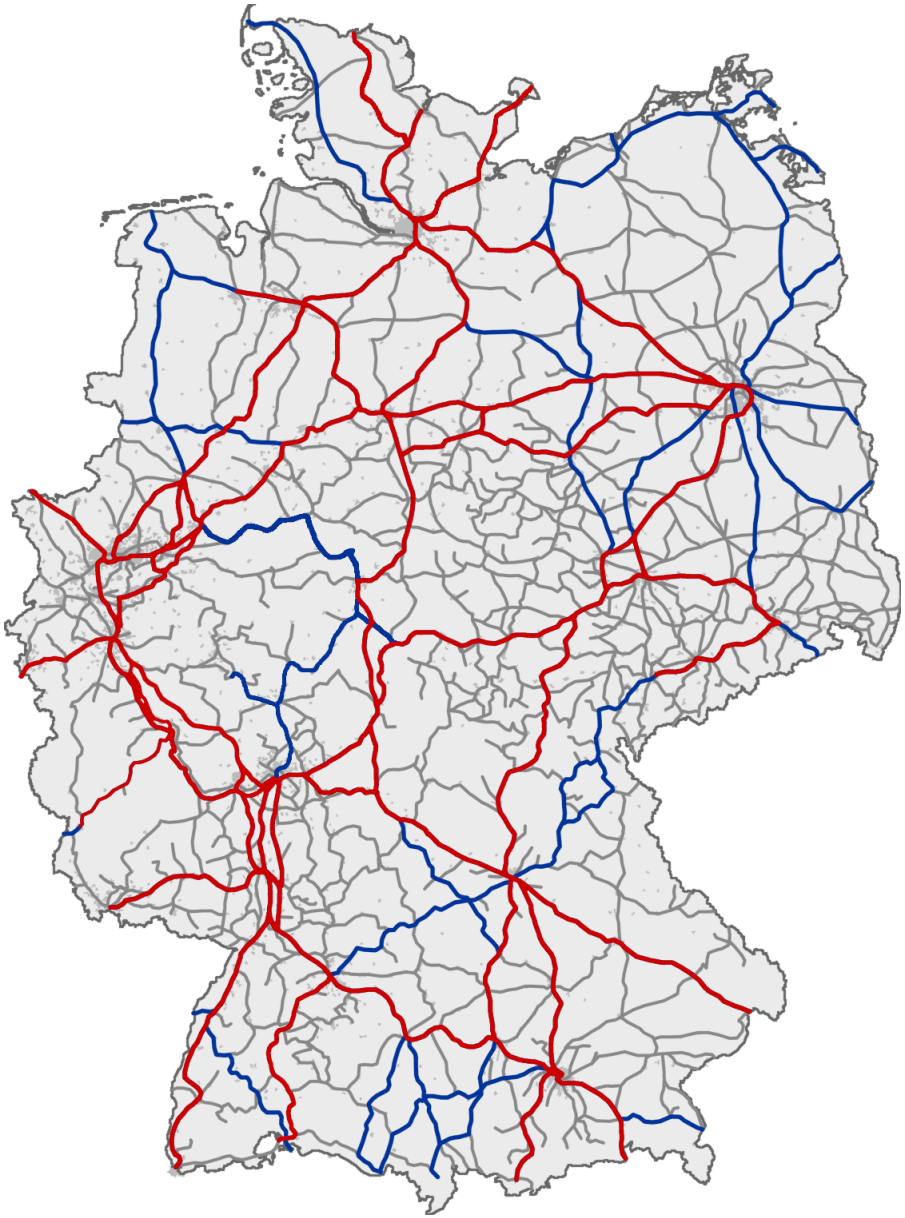
ArTe Work, Technology and Participation

Technische Universität Berlin

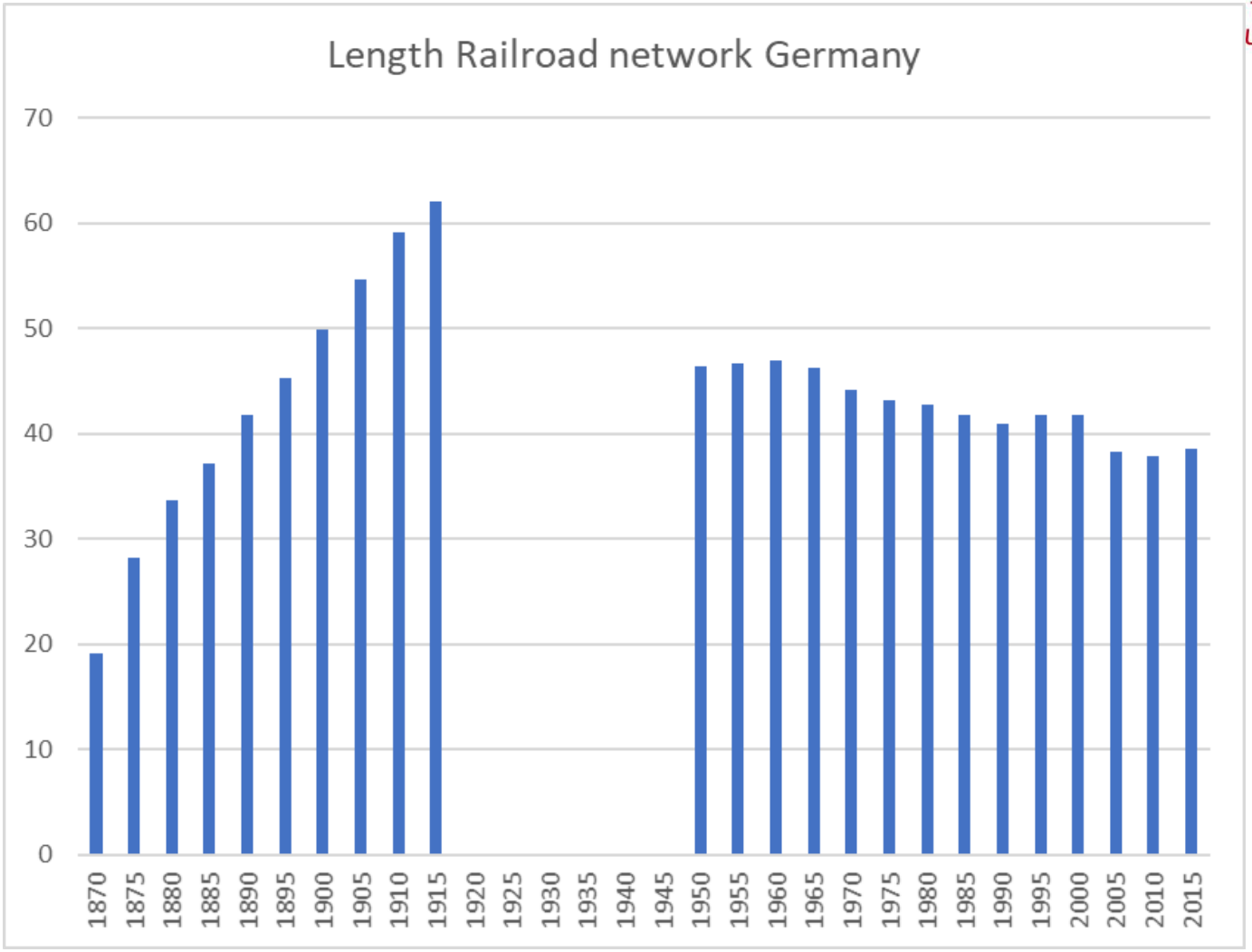
Railroad in Germany 1999



ArTe Work, Technology and Participation

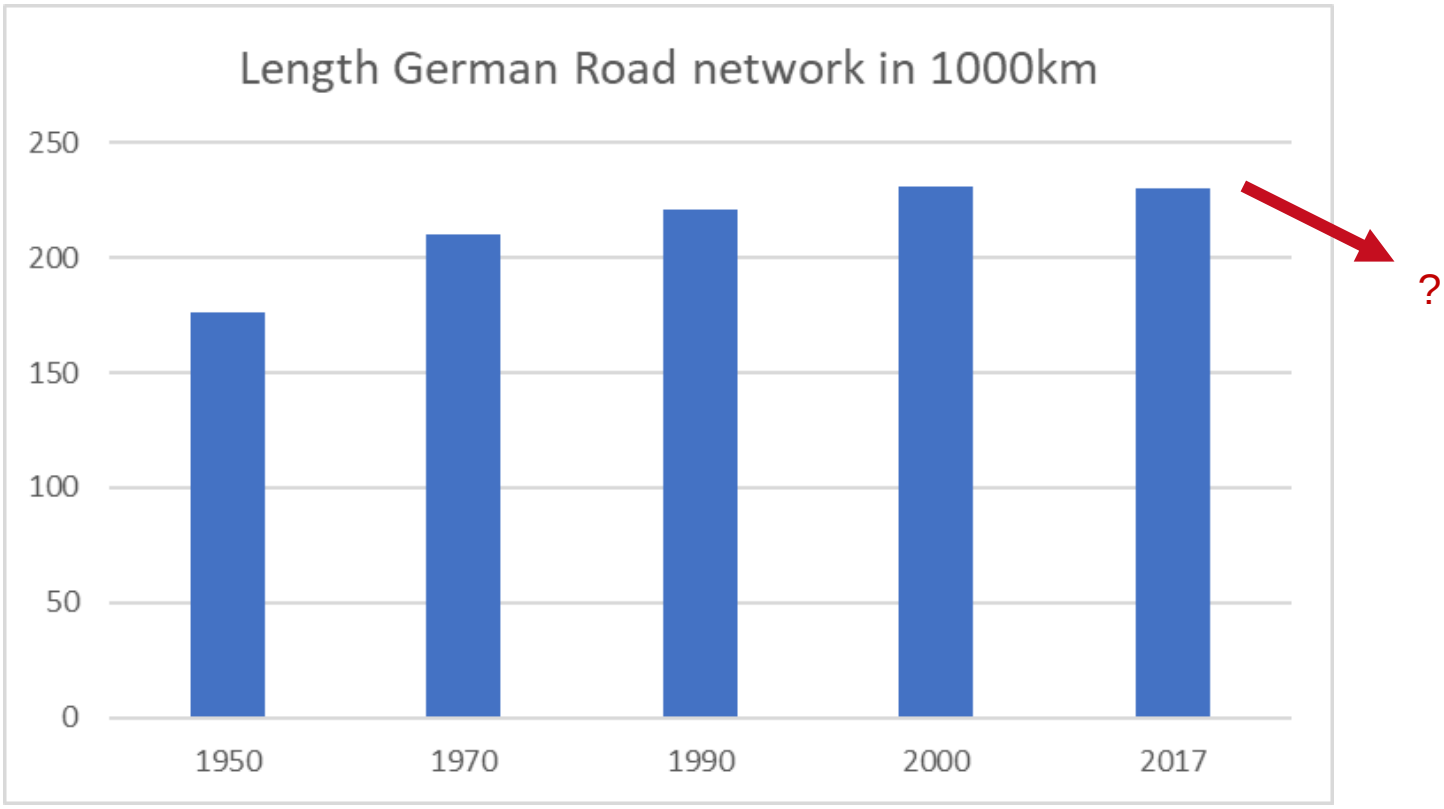


Railroad in Germany 2010



source: Own Design, Data: Verkehr in Zahlen, Destatis

And the Road?



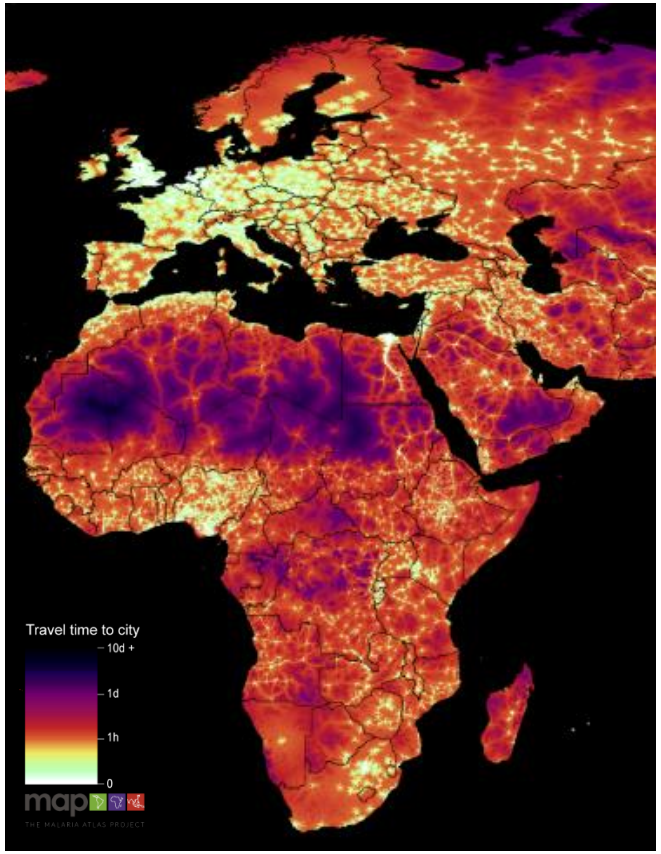
source: Own Design, Data: Verkehr in Zahlen, Destatis

What to do in the brownfield?

- Invest carefully in new infrastructure, it might not be needed
- General: autonomous driving will reduce space consumption on and of streets
- Re-use, re-purpose existing infrastructure
- small, intelligent vehicles on tracks and roads

The Greenfield: Africa

- Only 34% of the inhabitants of southern Africa have street access.



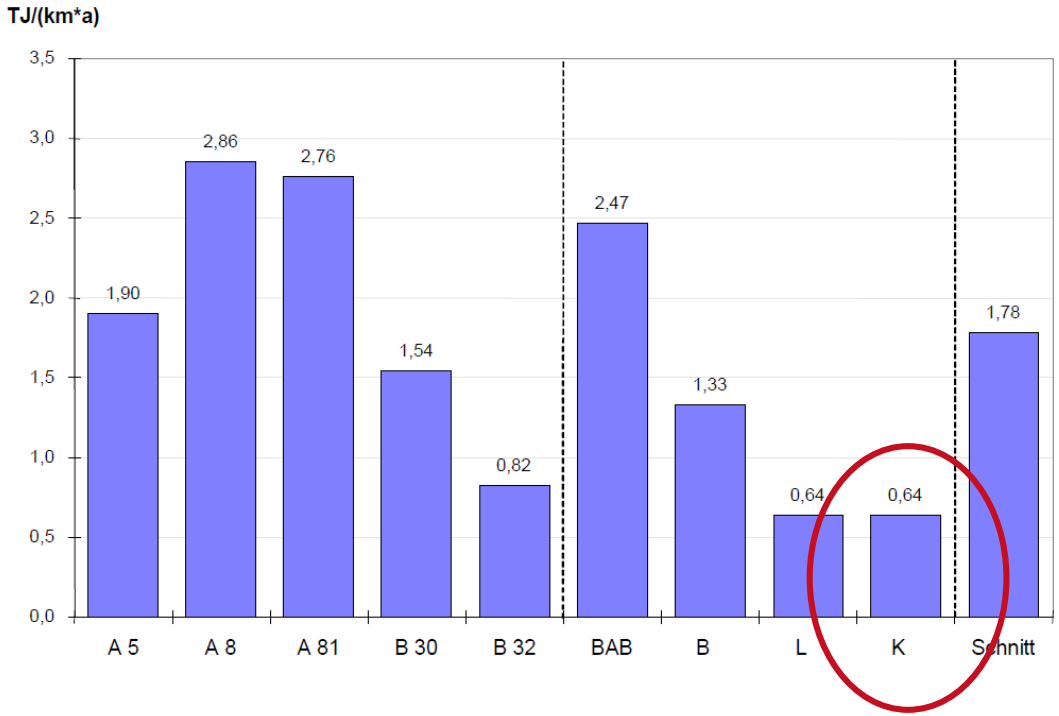
Rubal
Nash,
2015
The V

Table 1.1 Density of Paved Roads in Sub-Saharan Africa, Compared with Other Low-Income Countries

	Sub-Saharan Africa low-income countries	Other low-income countries
Density by area (km/1,000 km²)	10.7	37.3
Density by population (km/1,000 population)	269.1	700.7
Density by GDP per capita (km/US$ billion)	663.1	1,210.0

Source: Carruthers, Krishnamani, and Murray 2008.

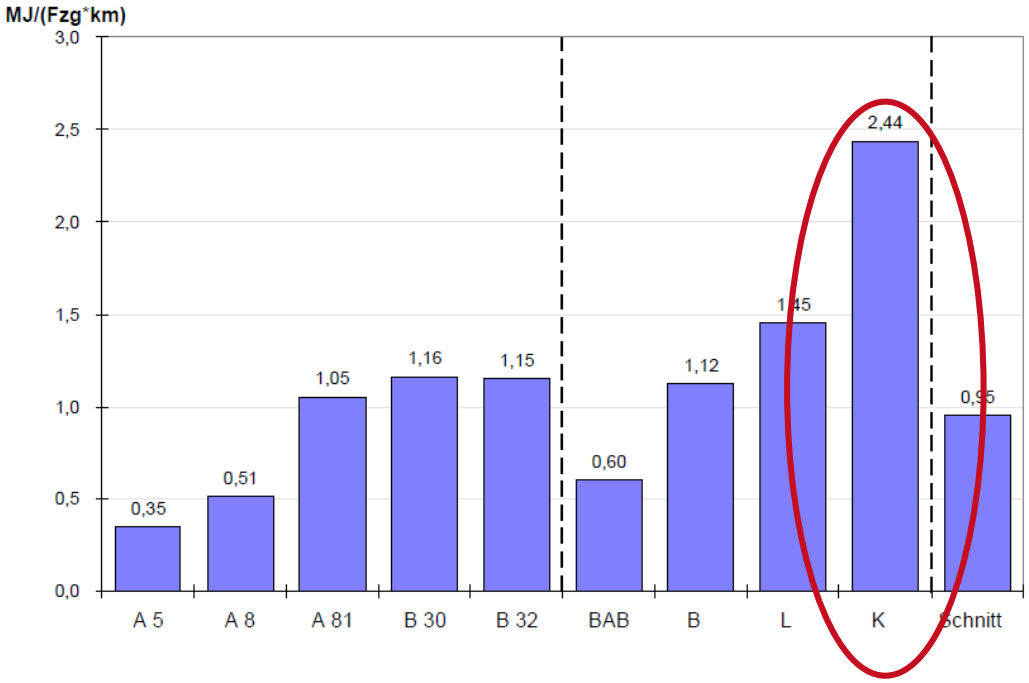
The village road is cheap…



source: Lampatzer et al., Vergleichende Untersuchung umwelt- und klimarelevanter Wirkungen verschiedener Verkehrsmittel bei der Erfüllung ausgewählter Transportaufgaben im Güterverkehr, 2000.

Abbildung 7.3-3: Kumulierter Energieaufwand für Bau, Betrieb und Instandhaltung ausgewählter Straßen sowie Mittelwerte für die Straßenklassen

… but is it worth it?



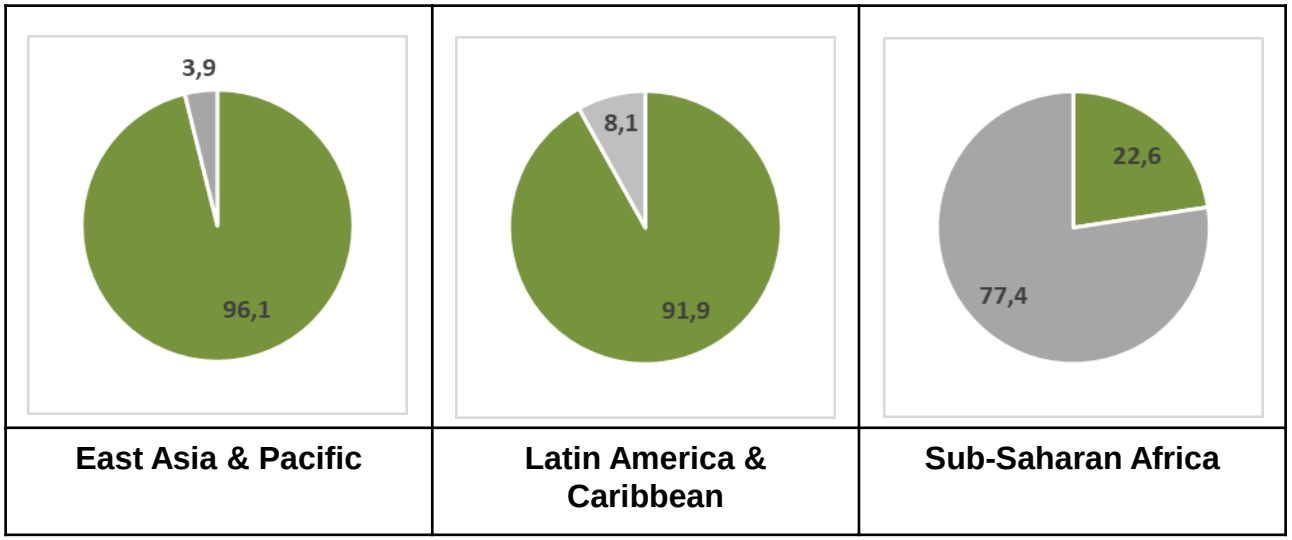
source: Lampatzer et al., Vergleichende Untersuchung umwelt- und klimarelevanter Wirkungen verschiedener Verkehrsmittel bei der Erfüllung ausgewählter Transportaufgaben im Güterverkehr, 2000.

Abbildung 7.3-4: Kumulierter Energieaufwand für den Bau, Betrieb und Instandhaltung ausgewählter Straßenstrecken bezogen auf die Streckenbelastung

Energy Poverty

- Energy Poverty: keine Anbindung ans Energienetz behindert die wirtschaftliche Entwicklung ländlicher Räume (und GHG-Emissionen durch Dieselgeneratoren).

Access to electricity, rural (% of rural population)



Offroad E-CargoBikes

source: anywhere.berlin

Projektidee

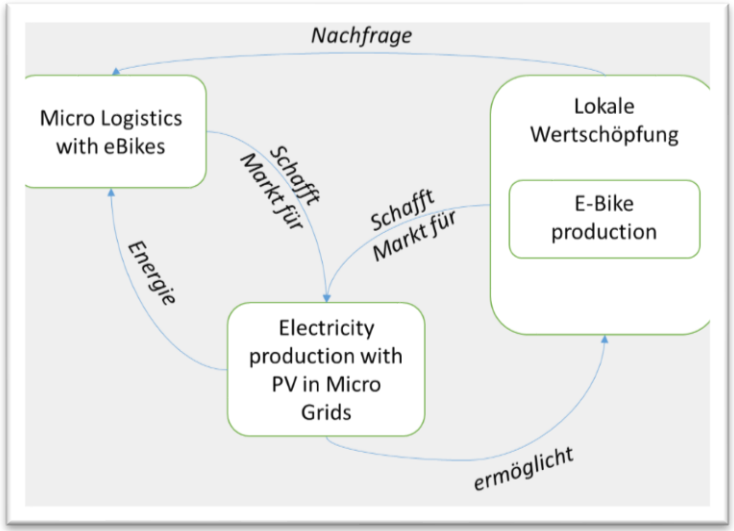
Dezentrale Micro-Grids basierend auf PV und Wind + dezentrale mikrologistik-Systeme basierend auf Elektromobilität.

- **Leapfrogging the Road:** Bereitstellung ländlicher Mobilität und Logistik ohne Straßen und die damit verbunden (direkten, indirekten und ökologischen) Kosten.
- **Leapfrogging the Grid:** Energieversorgung von Haushalten, Klein- und Mikrounternehmen und Transportsystem durch Mikro-Grids und Elektromobilität als Speicher.
- **Low-impact, zero-emission and labor-intensive sustainable mobility** and energy solutions.

Off-grid-solar power
\+ electric off-road cargo bike
\+ Local manufacturing
\+ existing track network

= *Green transport system on the cheap*
→ *Leapfrogging the road*

Pilot



Komponenten

(A) Mikrologistik mit elektrischen Off-Road Lastenfahrrädern

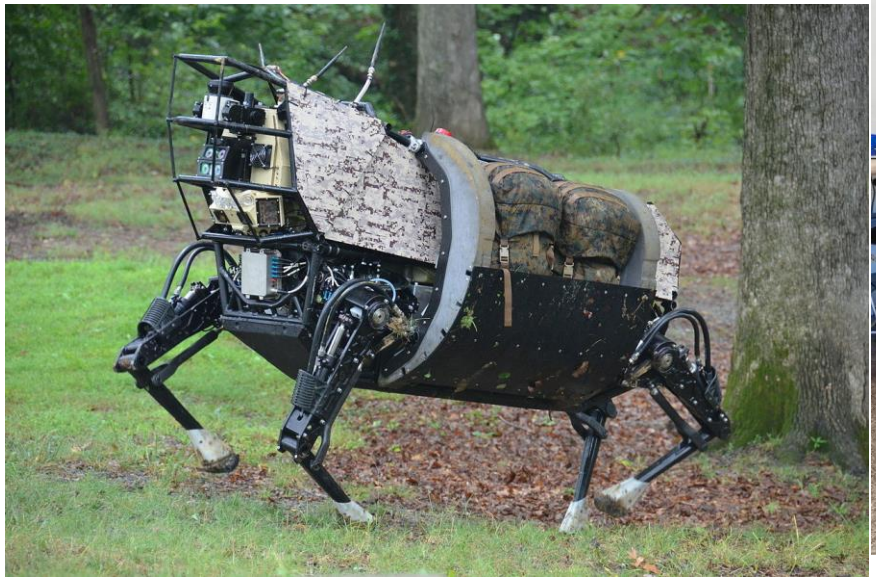
(B) Dezentrale PV-Micro Grids zur Energieerzeugung

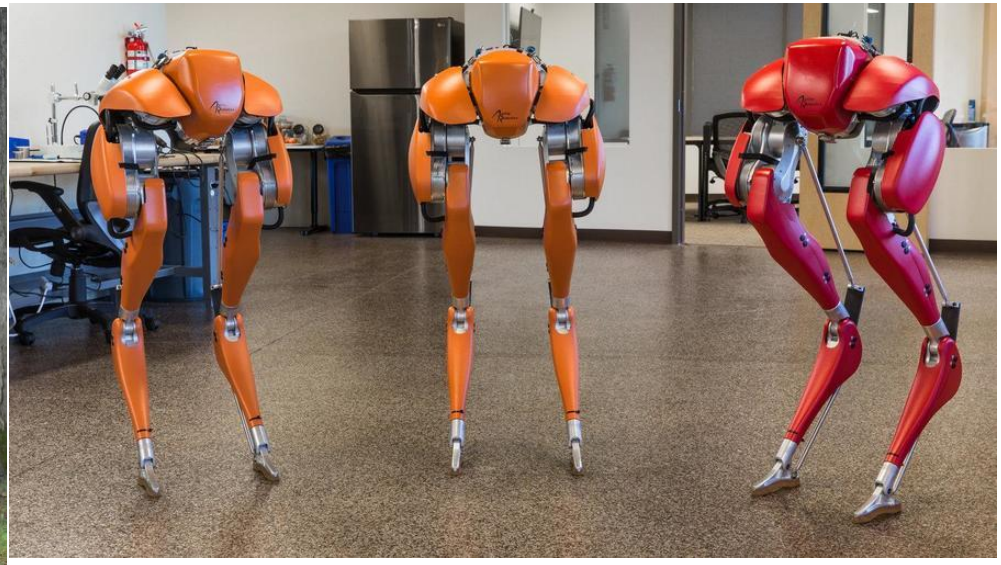
(C) Lokale Endfertigung von eCargoBikes in Micro Factories

Aktionen

- **intensive Einbeziehung von lokalen Anwohnern**, Stakeholdern und Nutzern, um mit diesen gemeinsam ein für die regionalen Spezifika und Bedürfnisse geeignetes Konzept und Plan zu entwickeln.
- Die Entwicklung von **Business- und Finanzierungsmodellen** für Logistik-, Produktions- und Energieerzeugungs- Micro-Entrepreneurship.
- **Schulung und Training** der Nutzer und Unternehmer.
- Die Evaluation, Impactanalyse (Modellrechnung, Messung).
- Überführung in ein **replizierbares Entwicklungsmodell**.

The Future of offroad?





New Systems without village road

				
	Walking	**Rail**	**Road (Truck)**	**?**
Vehicle	-	Train	Truck	eCargo Bike/UAV
Track Infrastructure	Trails	Rail network	Road network	Trails
Energy Infrastructure	Food	Electric Grid	Fuel Distribution	Off-Grid PV
Other		Train Station		
Flexibility	High	Low	High	High
Speed	Very low	High	Medium	Low
Load	Very low	High	medium	Low
Cost Infrastructure	Very low	High	High	Very low
Cost Vehicles	none	high	Medium	Low

Some Conclusions

- Urban Transport: get rid of individual motorized transport
- Avoid, shift and improve life quality
- Find new solution for commuting (e.g. working less)
- Re-Think rural transport: here solutions are needed and needed fast

- Be careful with infrastructure investment – you will be stuck with them
- Re-Use existing infrastructure
- Build system for a changing world

- Don‘t follow all the paths

Many Thanks!