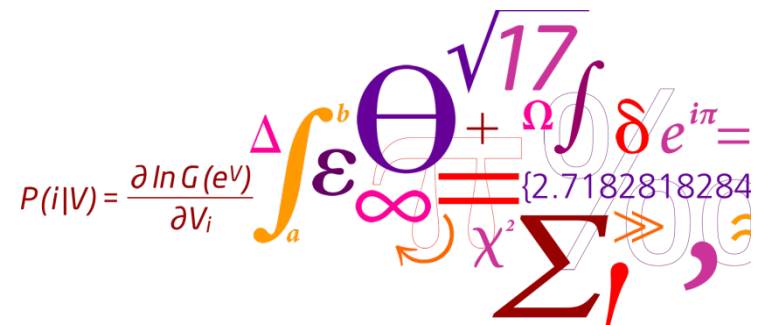


Mobility in the future

– How can we consider autonomous vehicles, shared economy and digitalization in the present decision making

Otto Anker Nielsen
 Professor
 Head of Transport DTU

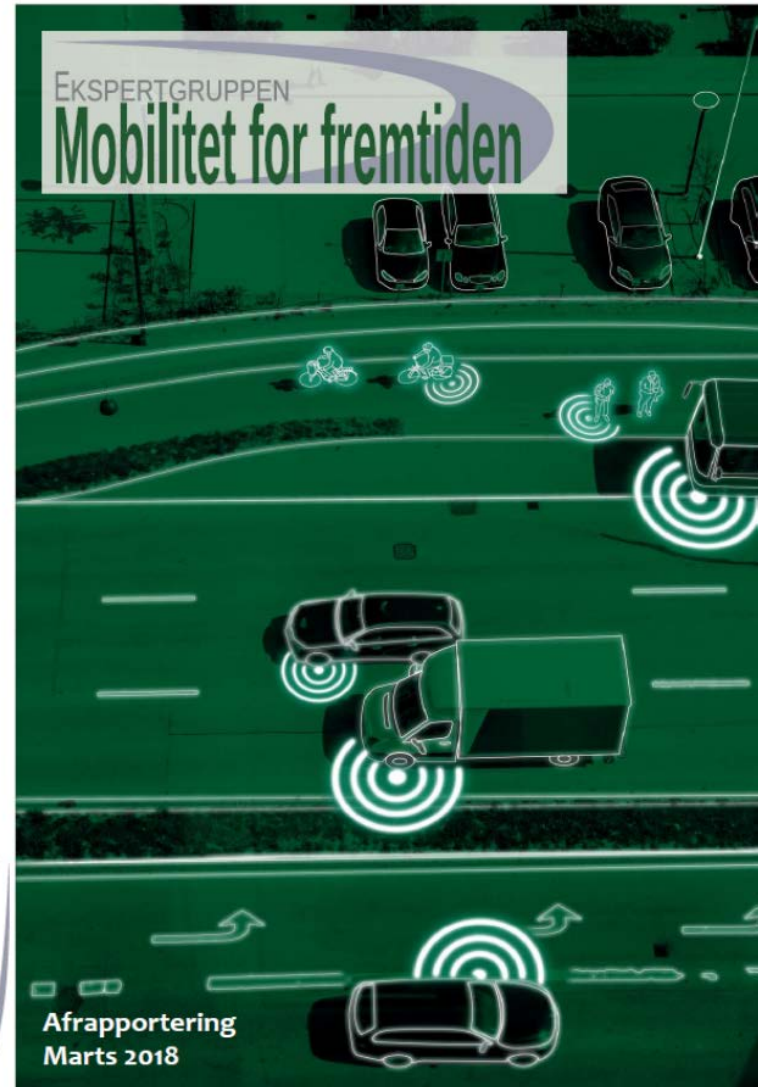


Danish transport minister expert group

Forside / Nyheder / 2017 / Ole Birk Olesen: Ny ekspertgruppe skal se på fremtidens transport

Ole Birk Olesen: Ny ekspertgruppe skal se på fremtidens transport

Transport-, bygnings- og boligminister Ole Birk Olesen (LA) nedsætter ny ekspertgruppe, som skal komme med anbefalinger til, hvordan vi bliver klar til fremtidens transport.



Terms of reference

Analyse

Possible future perspectives for the mobility and the transport system due to the technological transformation

The expert group was expected to

- Create an overview over central technological driving forces and societal trends in the transport sector
- Based upon existing knowledge describe how this may influence the demand after and supply of mobility
- Estimate how fast these changes will happen

Purpose:

Advise the ministry on the technological developments implications for the coming years transport policy decisions, i.e. <5-10 years

(41) **Søren Riis**
Associate Professor in Technology and science philosophy, RUC



(42) **Maria Wass-Danielsen**
M.Sc. Eng., Partner
Urban Creators



(49) **Otto Anker Nielsen**
Professor in Transport Models
DTU



(50) **Anette Enemark**
M.Sc. Eng, journalist, Head of Mobility
Movia



(51) **Mogens Fosgerau**
Professor Transport Economics
KU



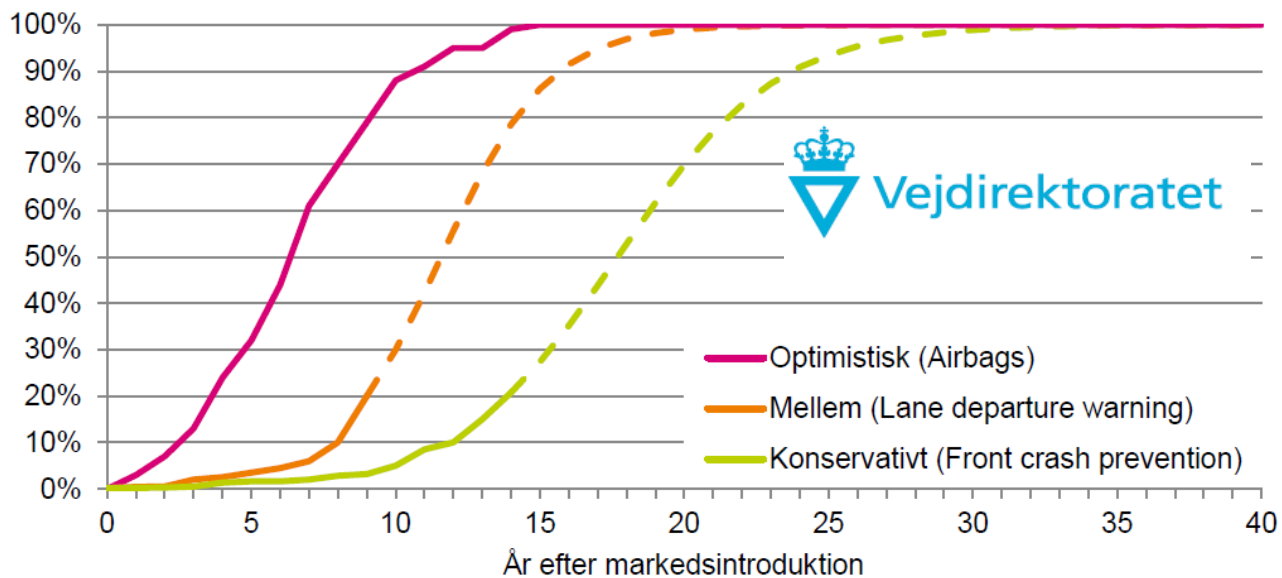
(56) **chairman Niels Buus Kristensen**
Economist., Ph.D. Research Leader
TØI



Timely concern

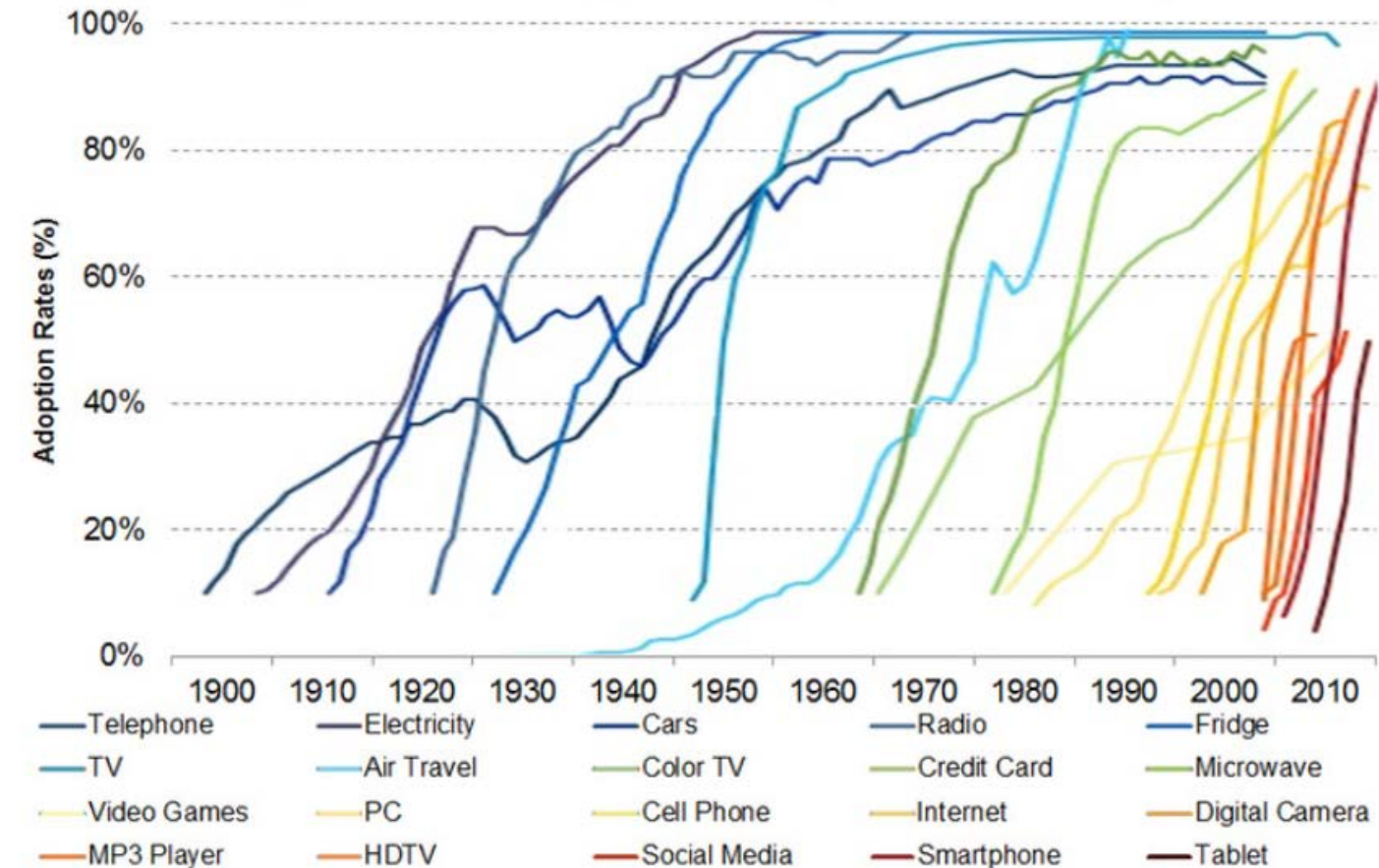
- Lifespan of decisions
 - Traffic contracts 7-12 years
 - Train rolling stock 20-30 years
 - Bridges/tunnels ~100 years
 - Railways/roads 100+ years
- Expected introduction of autonomous cars

Figur 6. Scenarier for indfasningen af automatiserede biler i MOTOBA



Adoption of new Technologies

Adoption of Technology in the US (1900 to the Present)



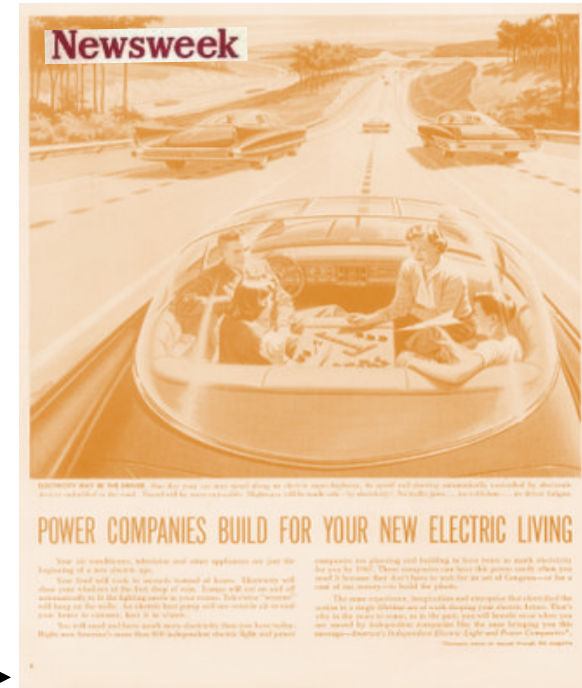
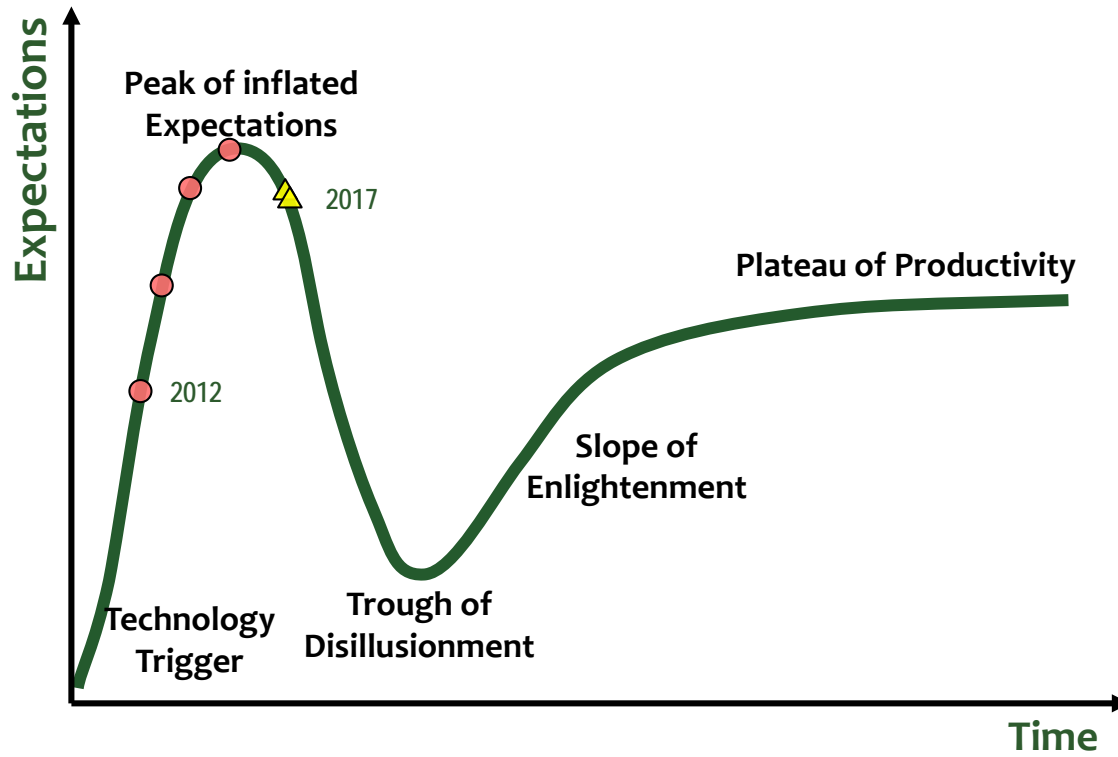
Market Realist

Source: BlackRock

(Blackrock)

<https://www.vox.com/2016/3/4/11161758/electric-cars-oil-crisis>

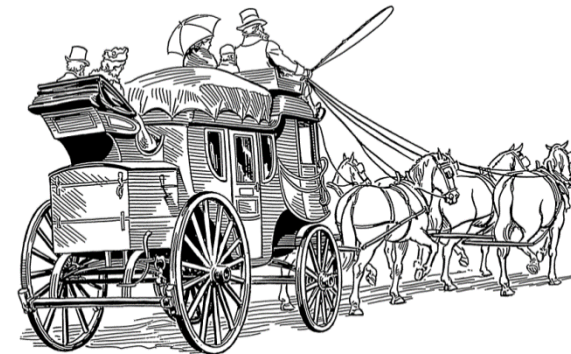
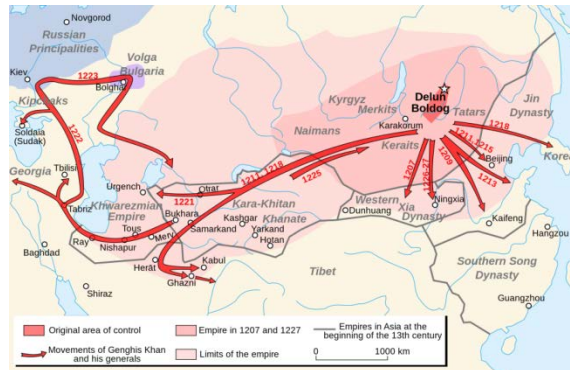
Gartner's Hype Cycle for emerging Technologies ...



Add i nNewsweek, Dec-1956

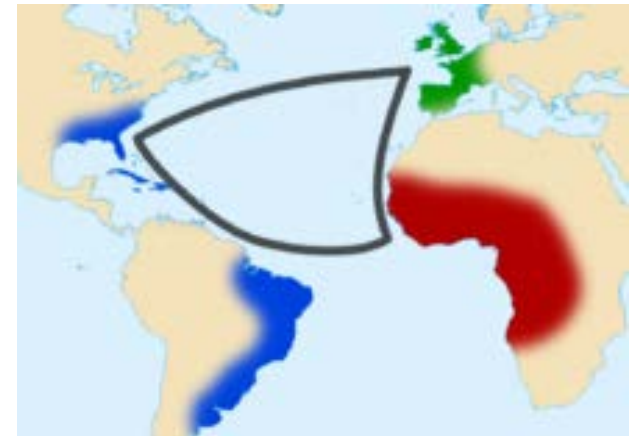
The first transport revolution

- Use of animals for transport
 - Gradually developed over thousands of years
 - Speed, load



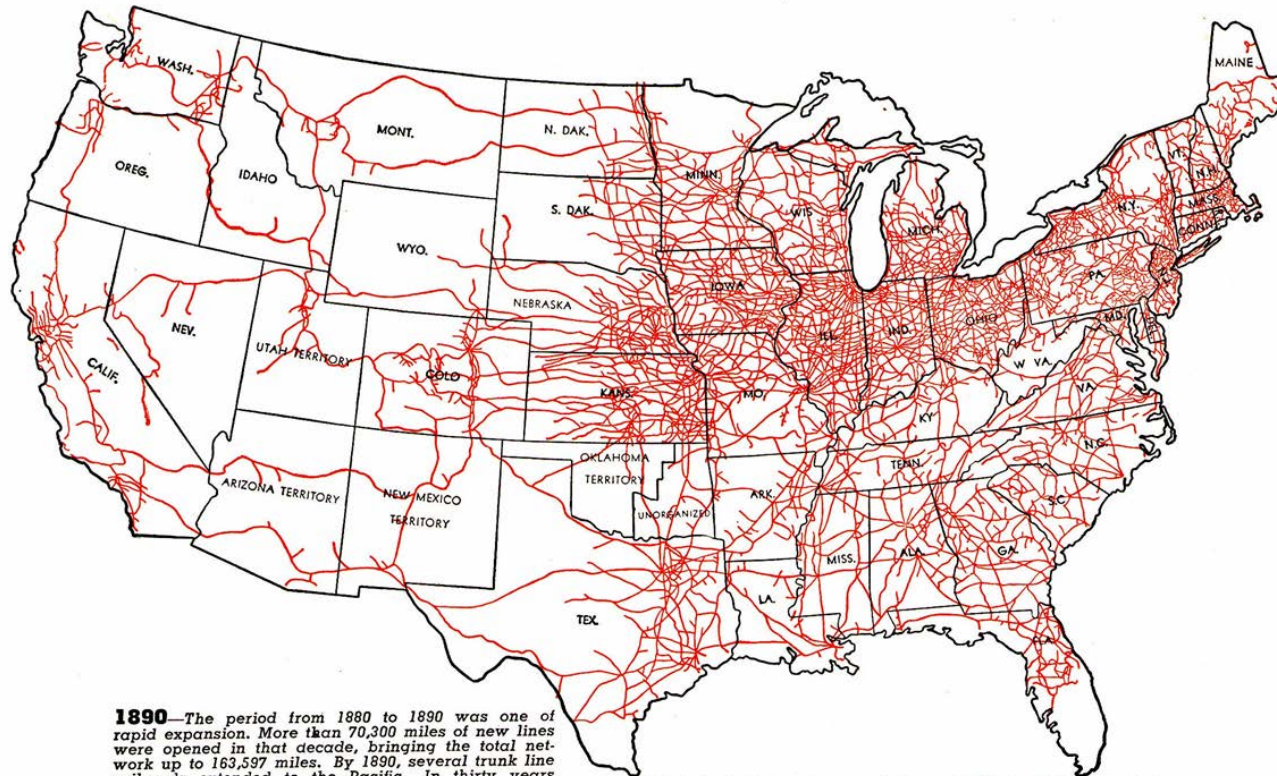
The second transport revolution

- Use of wind for sea transport
 - Gradually developed over thousands of years
 - Improved ship building technology and navigation



The third transport revolution

- Machines as power source
 - Fast technology development, US rail network development 1880-1890



1890—The period from 1880 to 1890 was one of rapid expansion. More than 70,300 miles of new lines were opened in that decade, bringing the total network up to 163,597 miles. By 1890, several trunk line railroads extended to the Pacific. In thirty years from 1860 to 1890, the total mileage of the region west of the Mississippi River increased from 2,175 to 72,389, and the population of that area increased fourfold.

Easter morning 1900: 5th Ave, New York City. Spot the automobile.



<http://www.businessinsider.com/5th-ave-1900-vs-1913-2011-3?r=US&IR=T&IR=T>

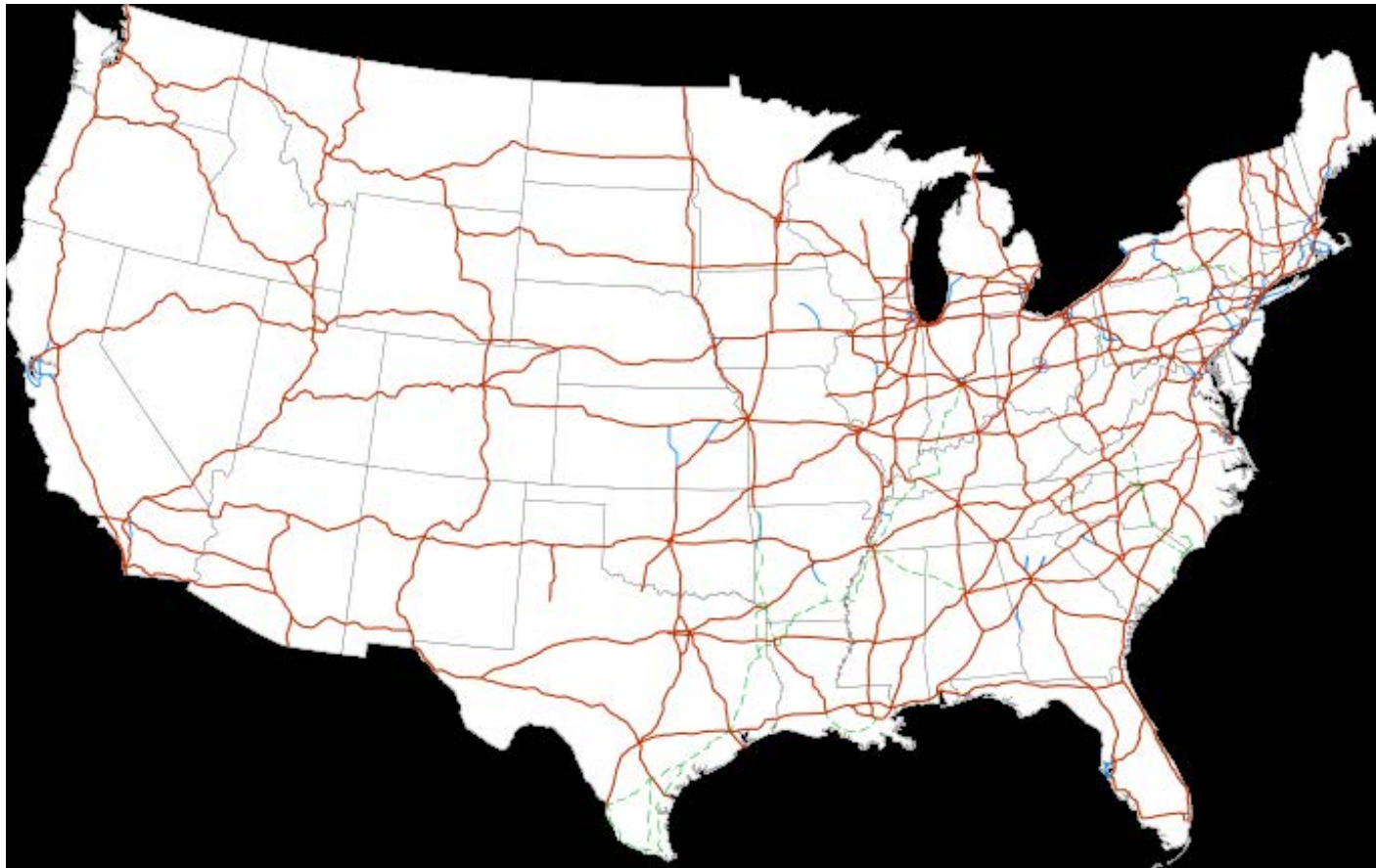
Easter morning 1913: 5th Ave, New York City. Spot the horse.



Source: George Grantham Bain Collection.

The third transport revolution,...

- Refinements of technology, passenger cars
 - US interstate highway system | 1950'erne



General transport options today

- Faster
- Larger volumes
- More reliable
- Cheaper (per unit)



...but capacity problems in the transport networks



Challenged urban transport infrastructure



Forecasted growth in congestion in Copenhagen

- Growth in delay time of 98% until 2025
- This could be reduced to a growth of 68% by unrealistically massive infrastructure investments
- Status quo in delay time could only be obtained by introducing road pricing

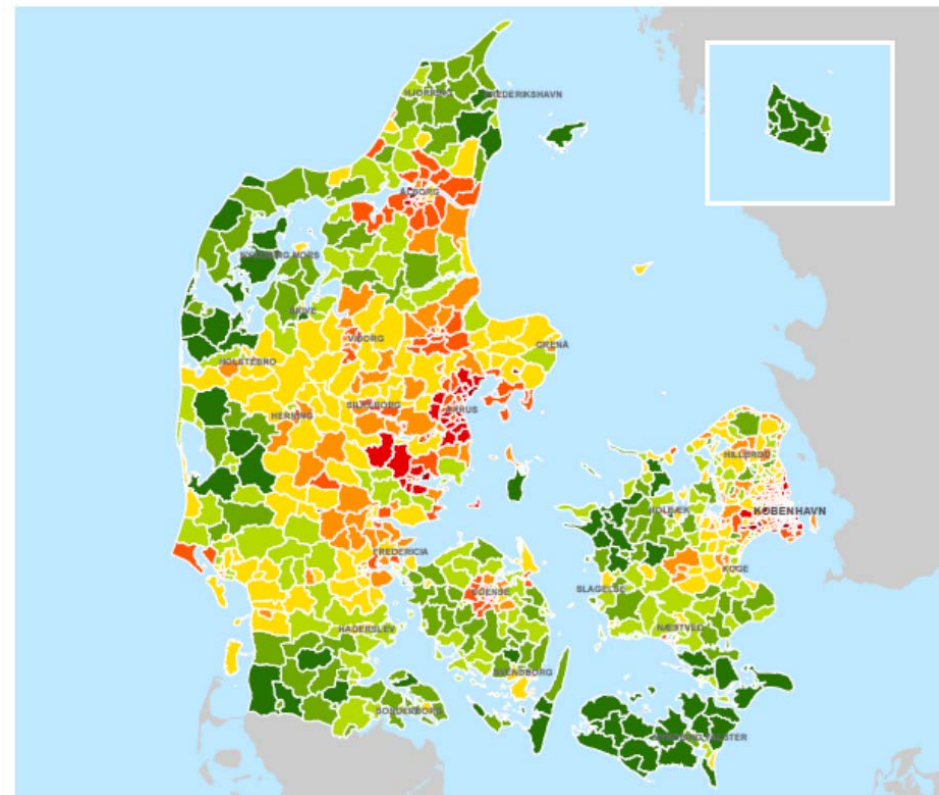


“ If we do nothing, the sheer number of people and cars in urban areas will mean global gridlock. Now is the time for all of us to be looking at vehicles the same way we look at smart phones, laptops and tablets: as pieces of a much bigger, richer network. ”

— **Bill Ford**, executive chairman, Ford Motor Company

Recent Demand changes in Denmark

- Urbanization
 - Challenges both in urban and rural areas
 - Changed commuting patterns
- Car ownership
 - Changes due to changed taxation
 - Energy efficient micro cars
- MaaS / shared economy
 - Enable non-car owners to use cars
- Changed goods transport and delivery concepts
 - Internet sale almost 25% of retail

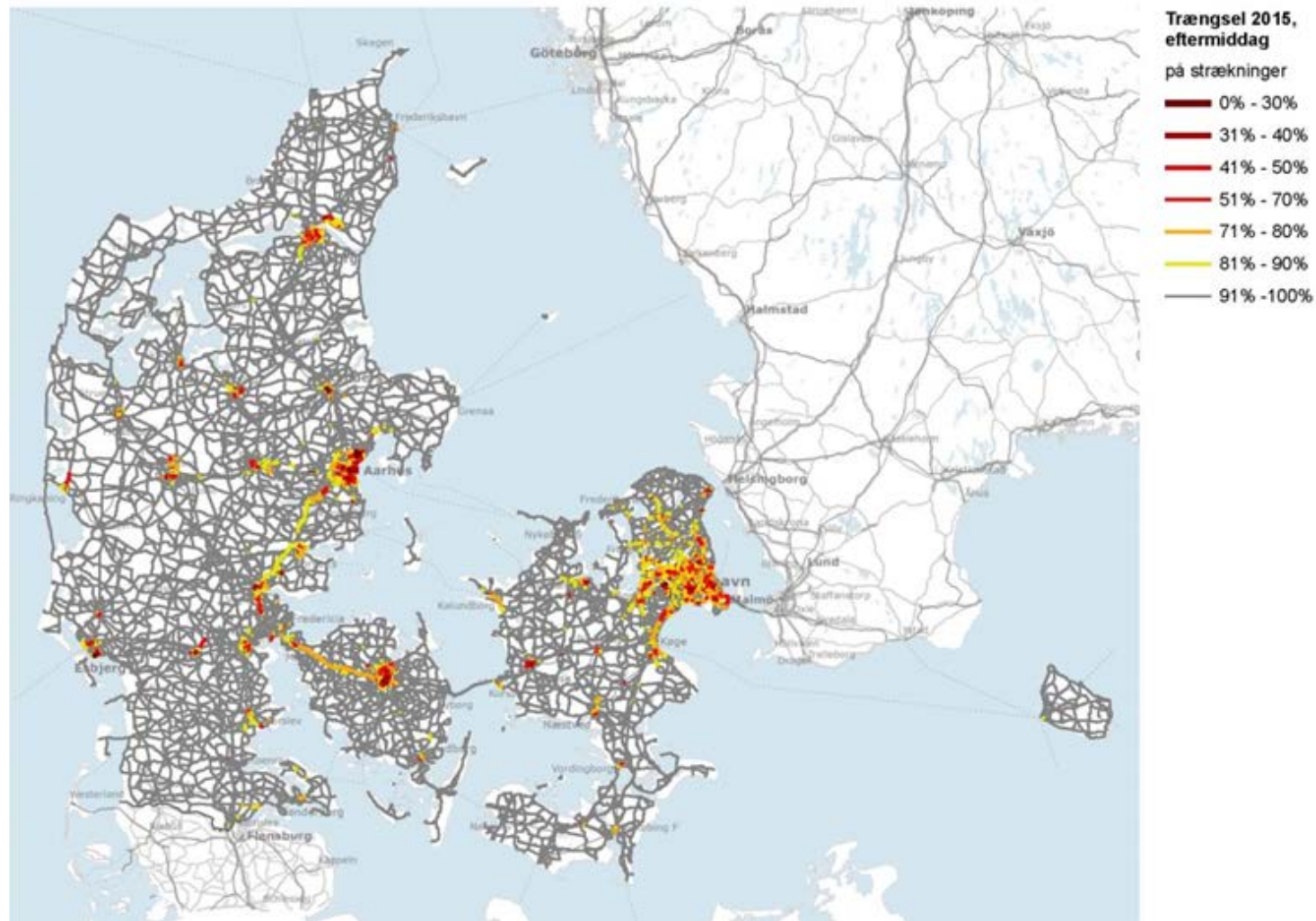


Population forecast in NTM/Statistics of Denmark, 2010-2030

<http://www.dr.dk/nyheder/penge/danskernes-internethandel-naermer-sig-100-milliarder-kroner>

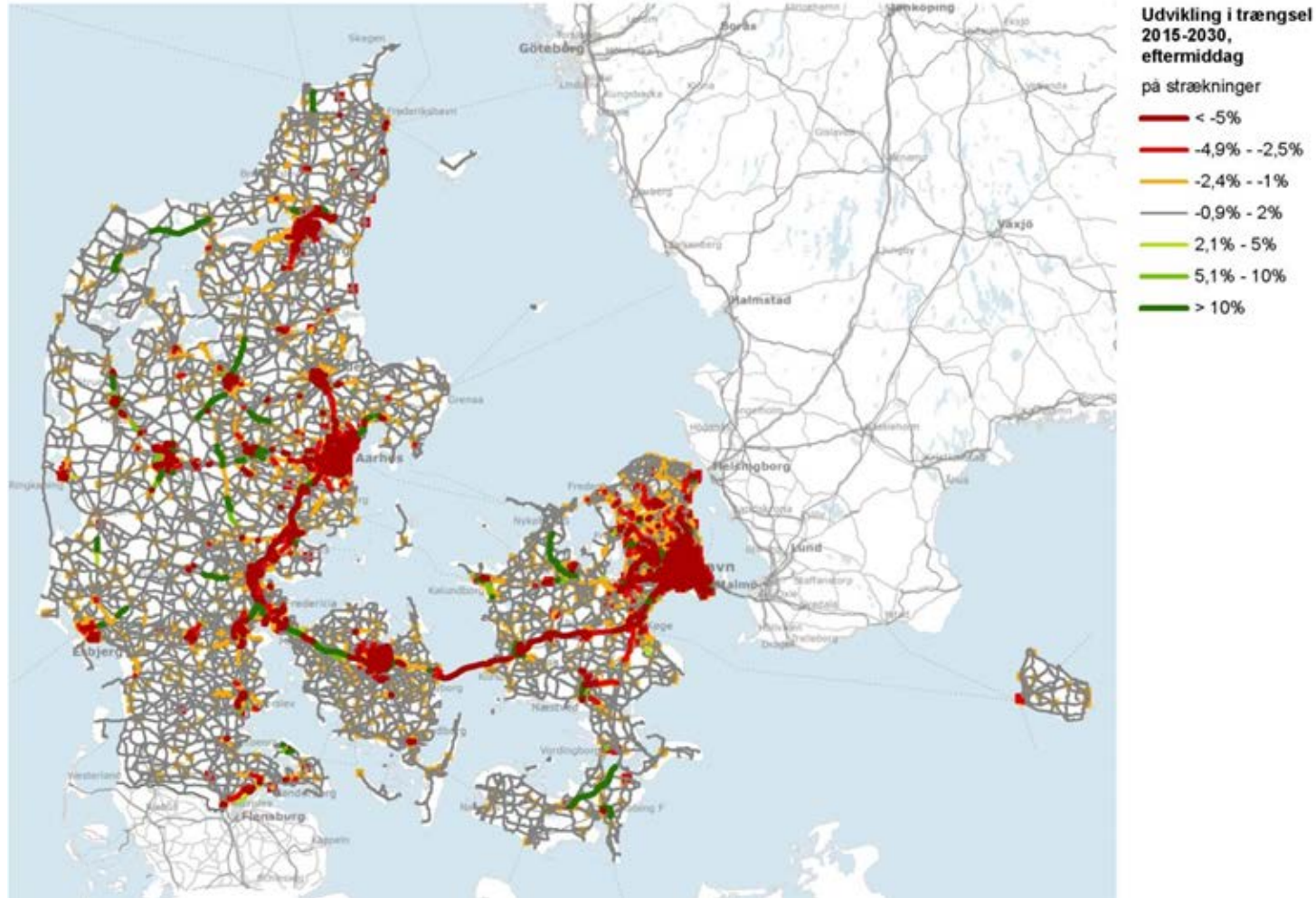
Afternoon congestion in 2015

Danmark



Predicted growth in road congestion (2030), national transport model

Danmark



The fourth transport revolution

- Digital age transportation with self driving Autonomous vehicles



Technological trends in the fourth transport revolution

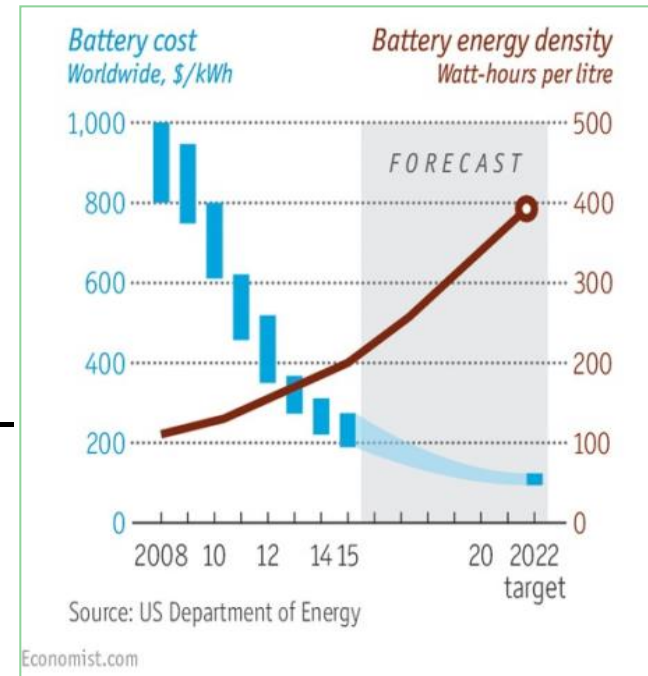
1. Electrification
 2. Shared economy+ MaaS
 3. Autonomous vehicles
 4. Digitalisation and big data + the cloud/www
- Geographical impacts

1 Electrification



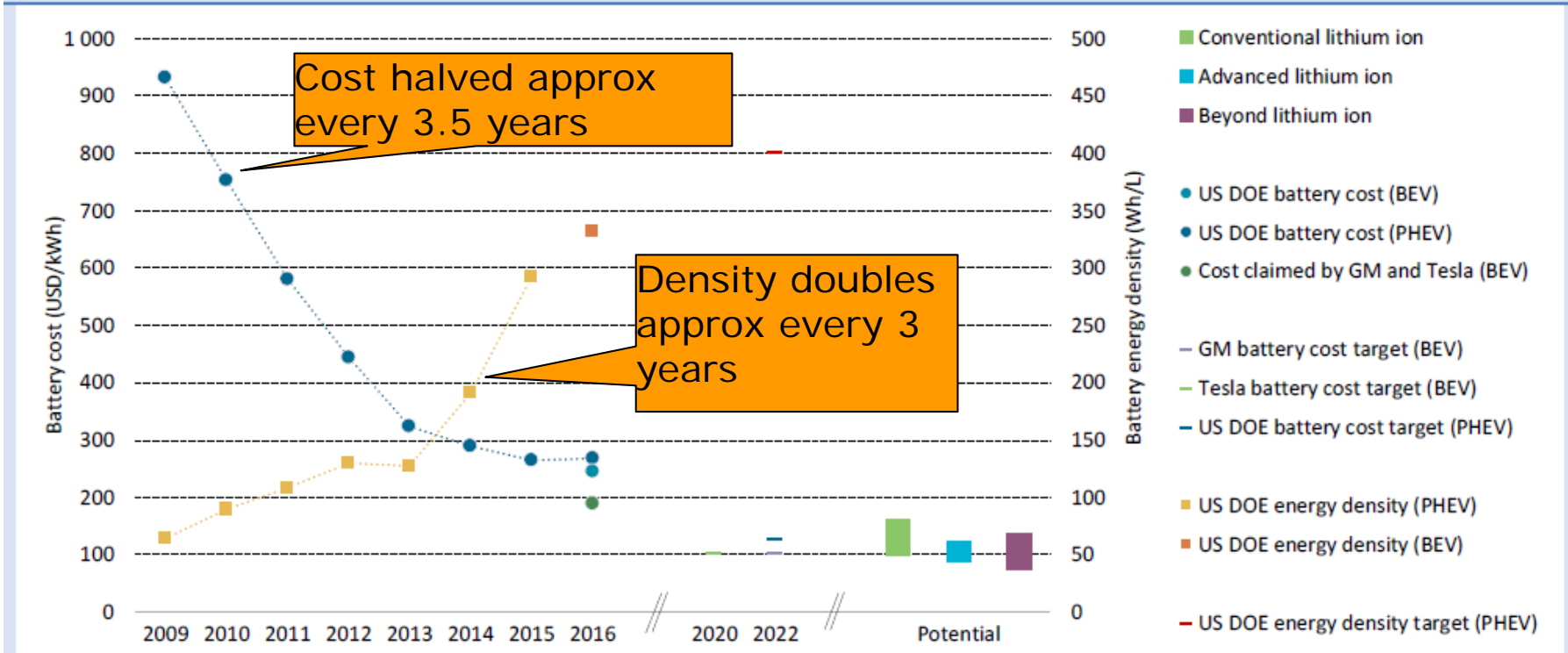
The climate agenda's consequences for the transport sector

- New passenger cars have to be CO₂-free from approximately 2035 to reach the 2050-target for Denmark's CO₂ emissions
- Economically competitive electric cars with sufficient range within 5-10 years
- Change to sustainable energy realistic – not a crucial barrier for future traffic growth



Moore's law on battery cost and density

Figure 6 • Evolution of battery energy density and cost



Global EV Outlook 2017
Two million and counting



Electrification may come fast

- **California** Zero Emission Vehicle (ZEV) Program
- **China** consider same policy
- **France** and **UK** have decided to ban sale of petrol and diesel cars by 2040
- **Norge**: Subsidies and benefits for EV's. New passenger cars and vans must be ZEV from 2025
- **Germany** and **Netherlands** discuss ban from 2030 and 2035
- **Paris** plan to ban all petrol and diesel cars in the central city from 2030

And car manufacturers gets the message...

- **GM** intensified R&D in EV after the Californiens Zero Emission Vehicle (ZEV) Program resulted in extra cost for them, and large subsidies to **TESLA** and **Toyota**
- **Volkswagen** (VOWG_p.DE) increase focus towards EV and plans to invest more than 20 billion Euro in "zero-emission" cars towards 2030
- **Toyota** will reduce CO2 emissions by 22% in 2020 and 90% in 2050

Ny el-lastbil imponerer: Letkørt og lydløs

24. januar 2018 15:30 | [Sådan](#) | [Tip redaktionen om en historie](#)

New electric truck impress:
Easy to drive and soundless

9

Billeder



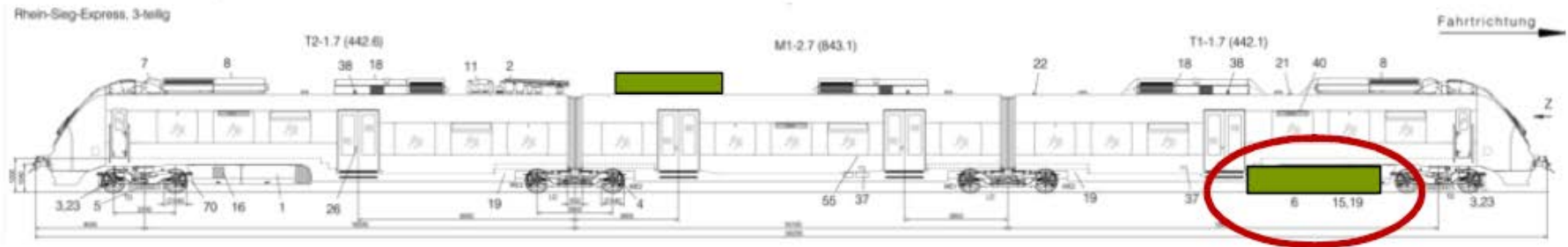
Fuso's eCanter er blevet mødt med stor spænding. Der er tale om en elektrisk lastbil, som har en passende rækkevidde. Foreløbig er den købt af en række tyske transportvirksomheder, som bruger den til forsøg med distribution i storbyerne Berlin og Stuttgart.

Battery trains

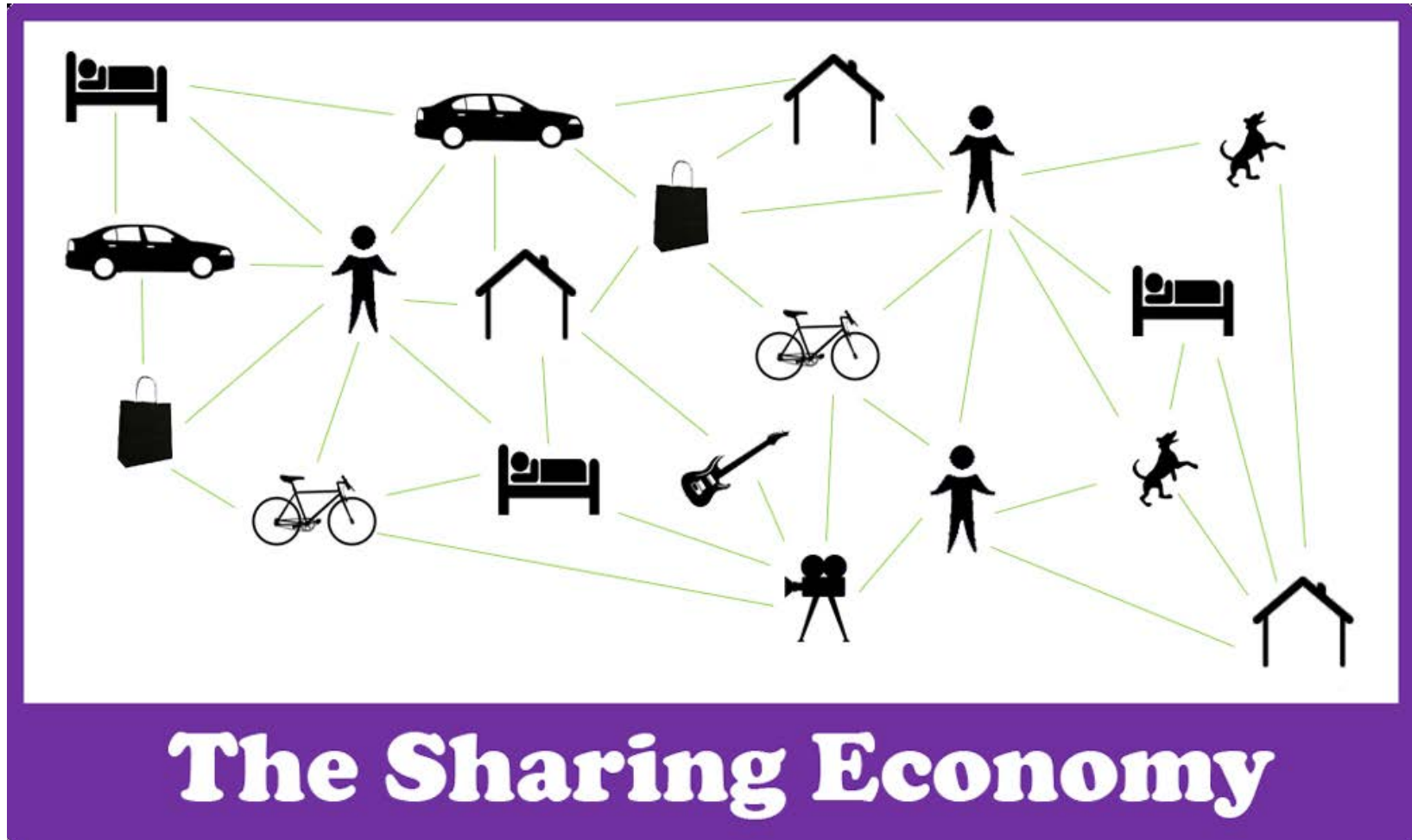


- Can charge at stations and at terminals
- Can charge along sections with power supply
- Can be achieved by retrofit diesel trainsets

Available space in Talent 2 EMU



2 Shared economy



Mobility as a Service (MaaS) Shared Economy

- Taxi variants



- Co-driving
- Carpooling



- Rented cars
/shifting drivers



Shared economy is not new,...



They all had high transaction costs measured with the scale of today,...

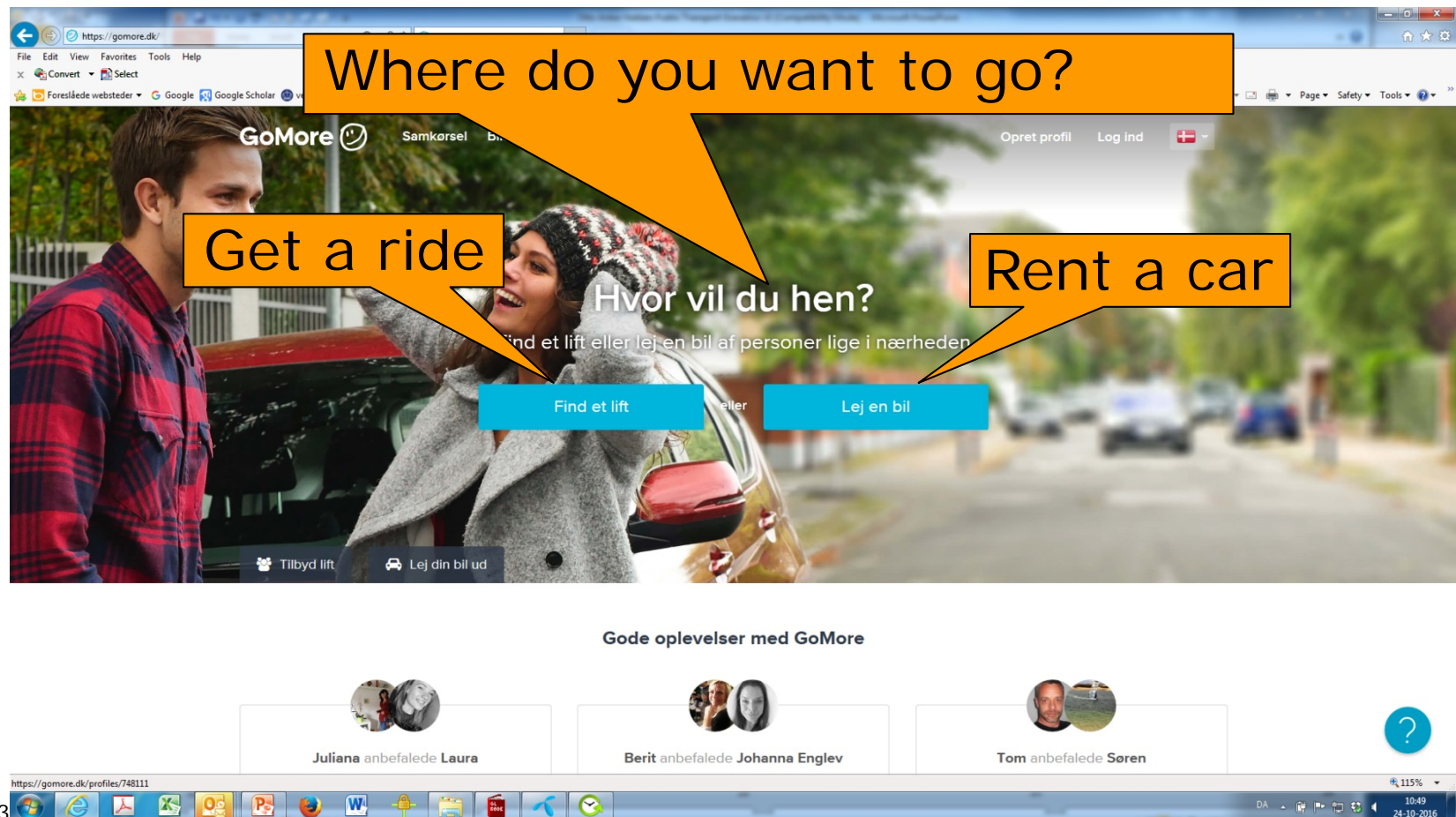
Shared economy of today



- Low transaction costs
- Eller seldom use with large benefit...
- Sometimes "creative" with regards to regulation, rules and taxes

Different concepts by same provider

- 10% of the Danish population is member of GoMore



Where do you want to go?

Get a ride

Rent a car

Hvor vil du hen?

Find et lift eller Lej en bil

Gode oplevelser med GoMore

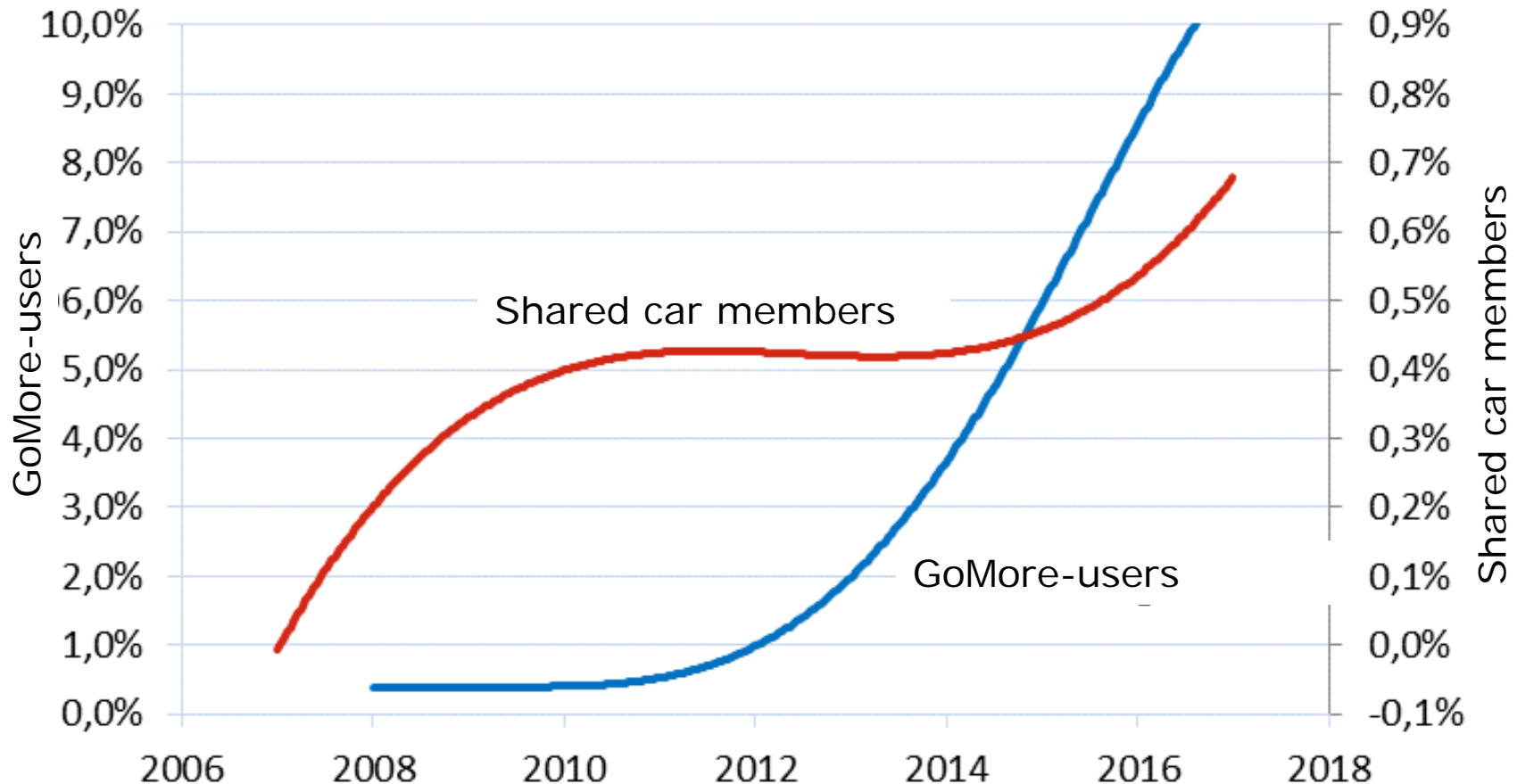
Juliana anbefalede Laura

Berit anbefalede Johanna Englev

Tom anbefalede Søren

3

Rapid growth in shared economy for car transport



Source: GoMores press releases on members and the national transport survey (TU).

Shared economy and new business concepts

Two ways to regulate the taxi business
 – 1 billion DKK as a difference!

2 MÅDER AT REGULERE

SKEL

DEN NUVÆRENDE REGULERING

LIBERALISERING DER TILLADER NY TEKNOLOGI

Present regulation;
 Seat sensors,
 taximeter with
 paper receipt

Liberalisation which allows new
 technology;
 Shorter waiting time, more "taxies",
 lower prices, more tax money
 1 Billion in socioeconomic benefit



Sædefølere

Taxameter
 med papirbon

I statskassen
 1. MIA.KR. I SAMFUNDSØKONOMISK GEVINST

CEPOS

Public transport – a bit provocative

- Drives from a place, where you are not located
- To a place, where you are not going
- At another time than you need



Shared economy provide more flexibility, but require critical mass



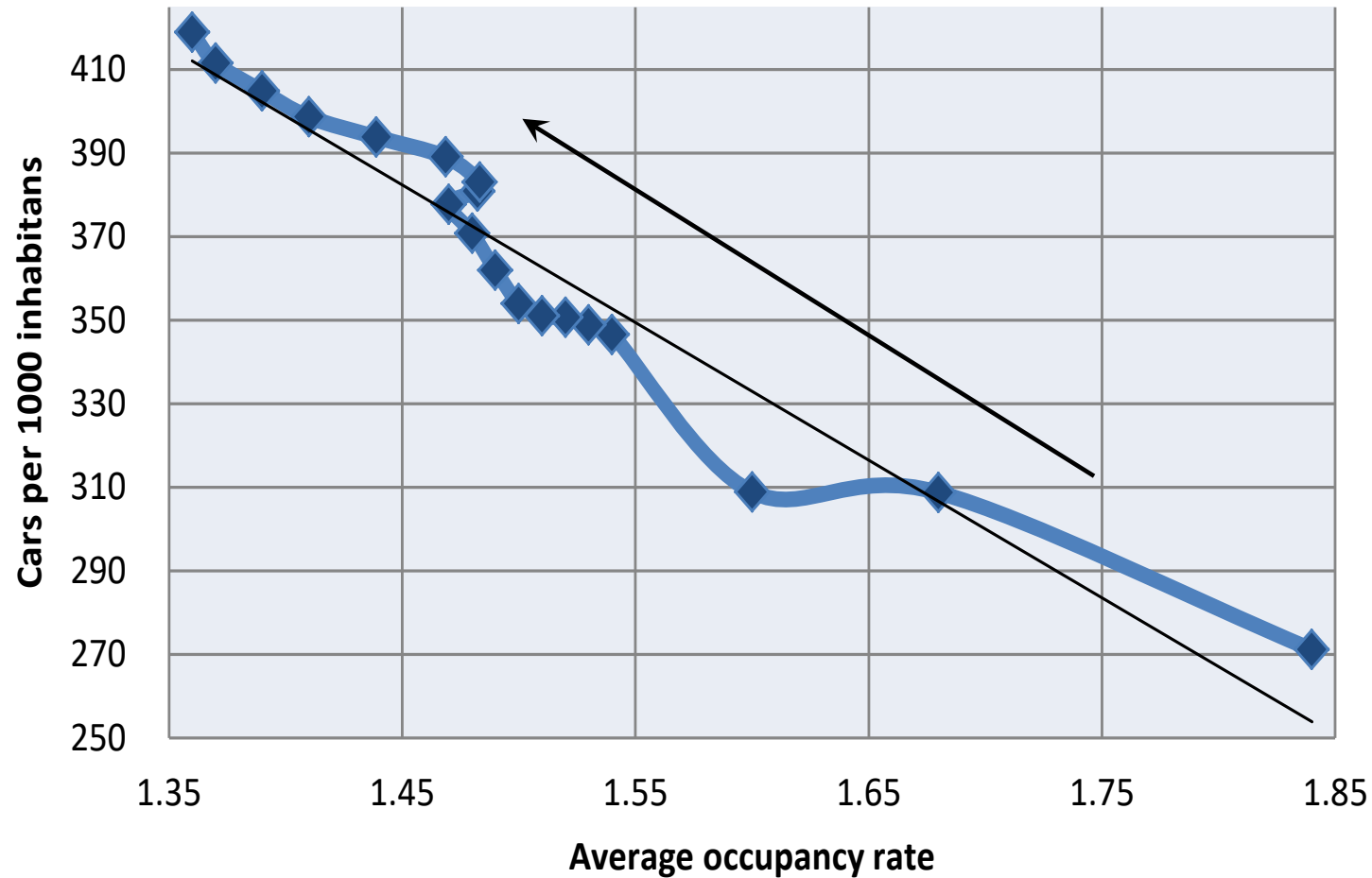
..., balancing trip patterns for car sharing



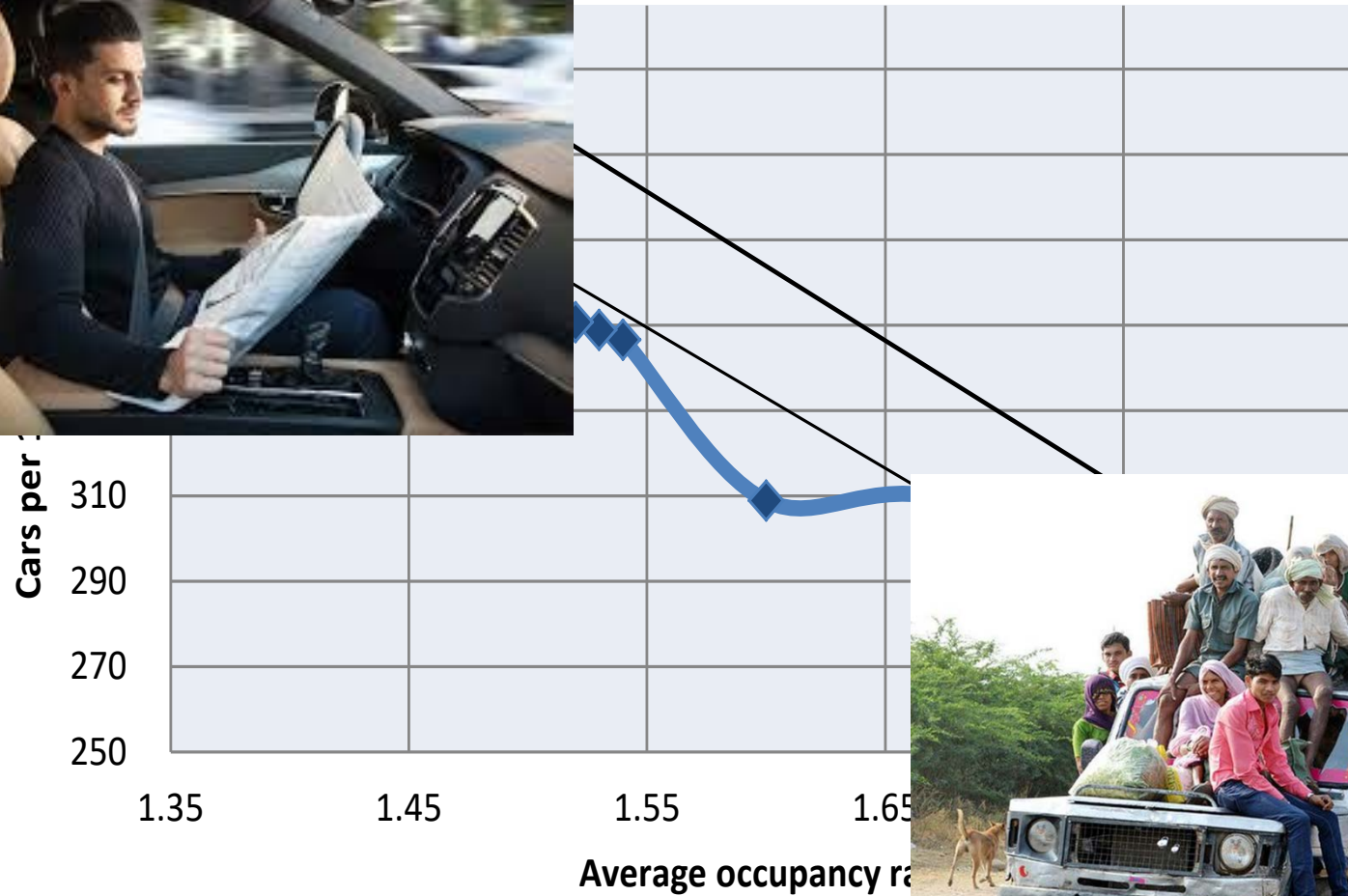
When we are not using a benefit ourselves, then somebody else can rent it,...



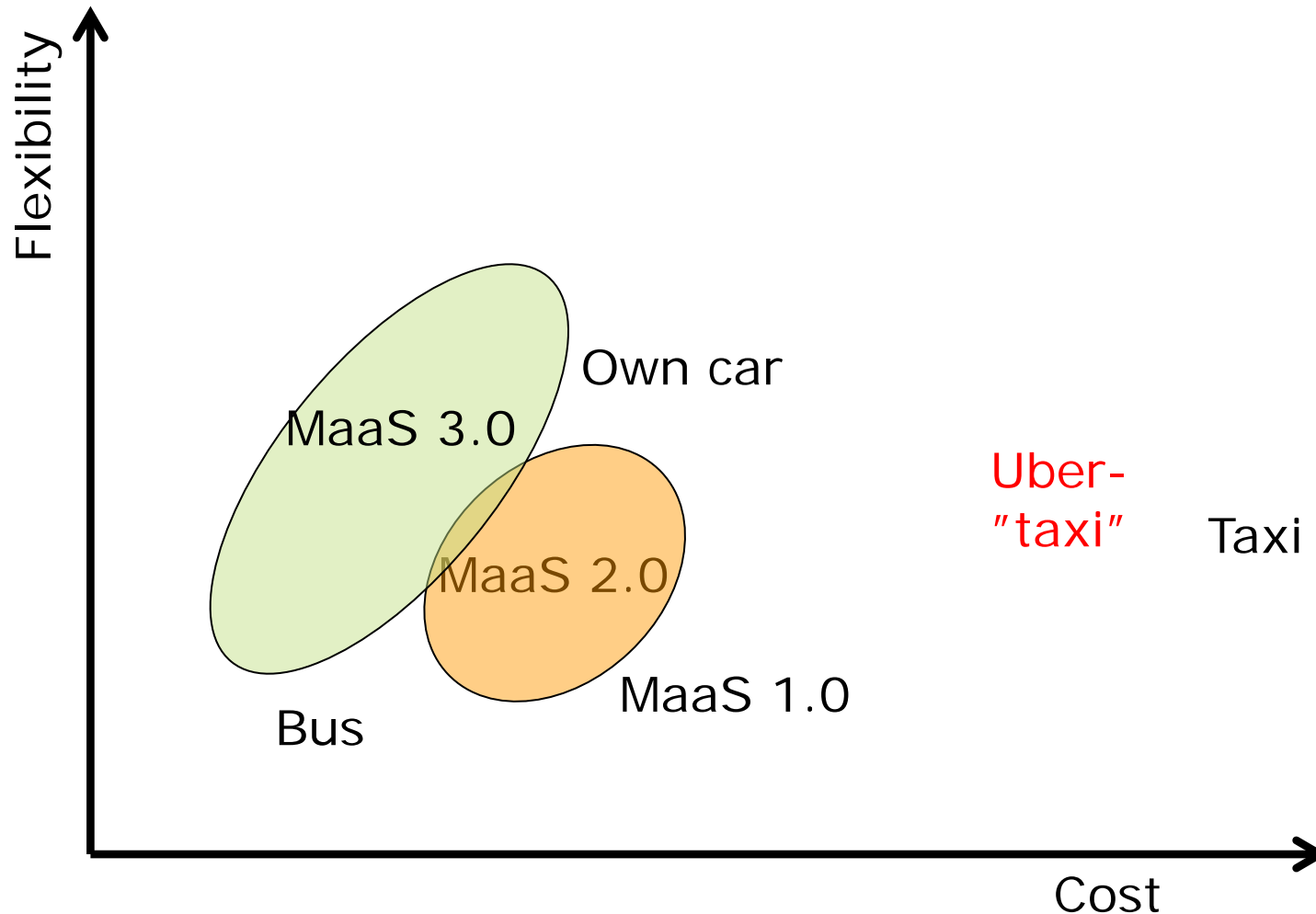
Development of car ownership and the average number of persons per car in Denmark the last 25 years



Economy and willingness to share, ...

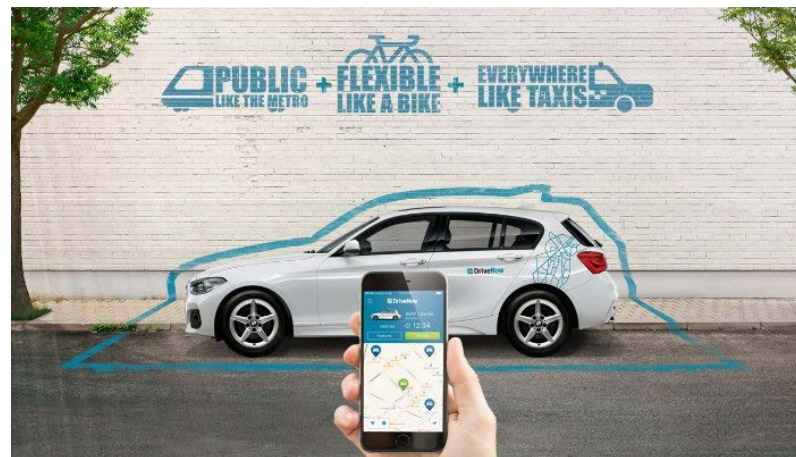


Shared economy and "Mobility as a Service", MaaS, as concept



New transport solutions

- Passenger cars
- Public flex traffic with driver
- Busses
- Trams/Light rails
- Trains
- Passenger cars
- Individual shared cars
- Shared cars (+1 per car)
- Flexible mini busses
- Busses
- Self driving BRTs
- Trams/Light rails
- Trains





Shared economy for goods transport

mover business

SERVICES ▾

OM MOVER

LOG IND

OPRET PROFIL



Danmarks største fællesskab af on-demand chauffører og vognmænd

Transport på dine vilkår - billigt, hurtigt og enkelt.



<p>AFHENTNINGSADRESSE Adresse 1</p>	<p>LEVERINGSADRESSE Adresse 2</p>	<p>KØRETØJ Køretøjstype ▾</p>	<p>TID & DATO Vælg dato og tidspunkt ▾</p>	
<p>INSTRUKTIONER TIL CHAUFFØR</p> <p>0/256</p>		<p>DATO Dato</p>	<p>FRA Fra</p>	<p>TIL Til</p>
<p><small>BEMÆRK: Der er én chauffør per vogn, så vær forberedt på selv at hjælpe. Prisestimat er inkl. 10 min. vente- og læssetid (5 min. først og sidst) herefter afregnes 5,00 kr. per minut. Beløb er ekskl. øvrige brugerbetaling (bro, færge, parkering mv.).</small></p> <p>Udvidet bestillingsform</p>		<p>---</p> <p>Estimeret pris ekskl. moms</p>	<p>BESTIL NU</p>	

Disruptive potential

mover business

SERVICES ▾

OM MOVER

LOG IND

OPRET PROFIL



Mover er en transportvirksomhed efter deleøkonomiske principper. Vi forbinder kunder med serviceorienterede chauffører og vognmænd i biler, varevogne og liftvogne. Til attraktive priser og uden skjulte gebyrer.



Øjeblikkelig transport

Med det største antal chauffører og vognmænd i Danmark, er vi ofte lige i nærheden.



30-50% billigere

Født ud af en deleøkonomisk tankegang, anvender vi chauffører og vognmænd der har tid og plads til overs.



Forsikret levering

Vi forsikrer både vores chauffører og dine ting, så alle er i trygge hænder.



Live tracking

Følg din chauffør på hele turen, så du slipper for unødigt ventetid.

Immediate transport (fixed time window)

30-50% cheaper

Ensured delivery

Live Tracking

What will be the impact of new shared economy solutions?

- They may create new better transport options for persons at some situations
- Goods transport can be cheaper and more reliable
- Public monopoly solutions will probably lead to a very slow and limited introduction
- Private solutions can be supported by constructive regulation, as compared to creating regulatory difficulties
- Subsidy may follow the persons not operators/companies

3 Autonomous vehicles



Five levels of automation

[SAE J3016 \(Jan-14\) Driving Automation Definitions](#)

Self driving features – seen from the user:

- **Self driving:** Driving – under certain conditions – does not require attention from the driver.
 - The driver can therefore better utilise the travel time
 - BUT must be ready to take over driving
- **Driverless:** The vehicle can completely drive itself from door-to-door
 - New users without driving license
 - Empty repositioning

The self driving features can be limited to certain parts of the road network, and by weather speed, traffic conditions, etc.

Different degrees on assisted driving

- More safe – maybe!
- More comfortable - probably
- Better use of time (VoT) – but how much does this matter?
 - VoT for passengers?
- Better use of capacity (on motorways), however, dependent on critical mass
- Improved traffic control?
 - Dependent on level of connectivity
 - Traffic signal control, etc.
 - Public versus private marked



Three paths for automating passenger transport

- three business concepts

Development path

1. Gradually automating private cars

Self driving private cars



2. Fully self driving "taxis"

Driverless taxi concepts

- 'Taxis'
- 'Shared taxir'
- 'Taxi busses'

Mobility-as-a-Service



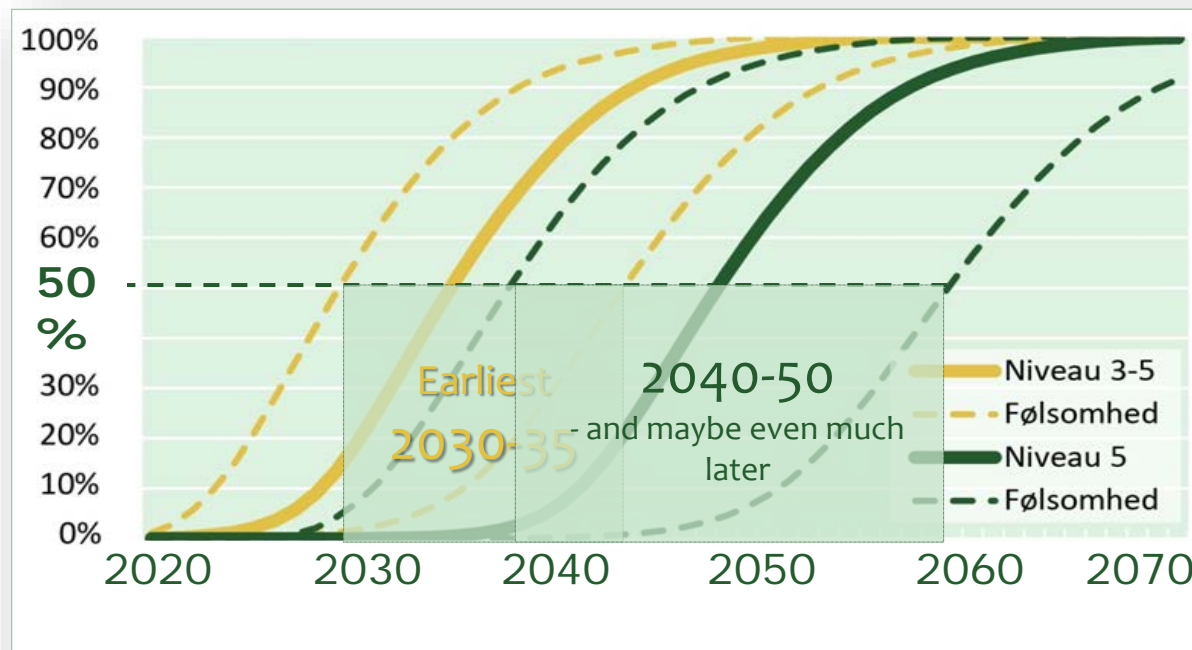
3. Driverless public transport systems

Automated public transport



Large share of driverless private cars are possible long out into the future

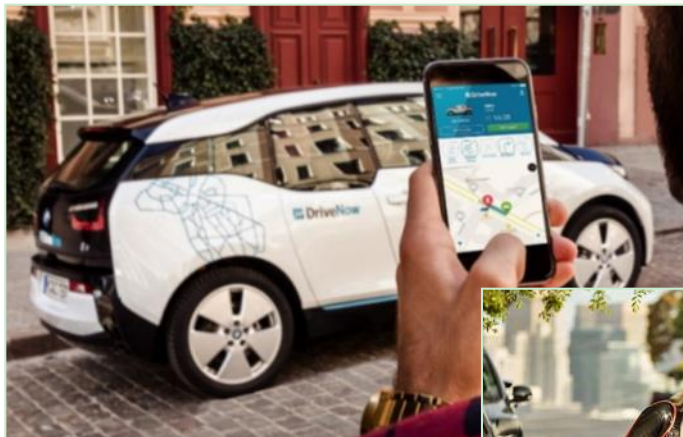
- but there is large uncertainty and lack of consensus about the time perspective



1. **Introduction** to the market
2. New technologies penetrates slowly into the **market for new cars**
3. Share of the **car stock** increase slowly due to the long life of cars

The Danish value-based car taxation even slow down this transition as compared to other countries...

New business models interacts with the automation



Car sharing



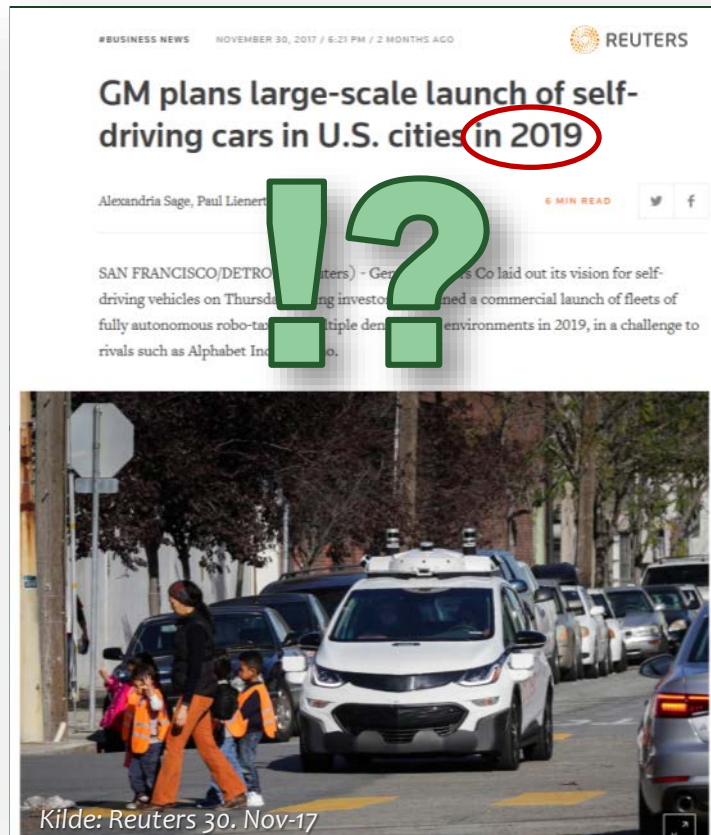
Mobility as a Service



Ride sharing

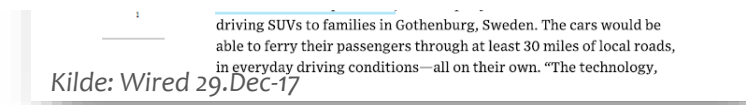


Driverless taxi concepts



- Driverless taxis may be introduced much earlier than driverless cars
 - Automation of taxis develops as driverless from start to save the salary

Is this difference in expected time of market introduction between private cars and taxis realistic?



Driverless busses

- Today: Mini busses for niche markets
Later: Normal busses
- Driverless busses will probably also appear before private cars
 - Salary costs strong driver
 - Fixed route makes it possible to adapt the infrastructure, establish support systems and interact easier with the other traffic

Stockholm får Skandinavien's første førerløse bus

Den førerløse bus har plads til 12 passagerer og vil følge en programmeret rute på 1,5 kilometer.

ONSDAG D. 24. JANUAR 2018 KL. 10:57



ADRIENECYTO - FUGL I sandtetsavnne 2017 En vinstfuld førerløs bus kørte staden lang på en 300 m. lang lørdag. Det er Aalborg, fredag d. 30. juni 2017.

THE STRAITS TIMES

NTU and Volvo Buses to develop electric, driverless buses by 2019

ik 24. Jan-18



Through a partnership inked on Thursday (Jan 11), Volvo will provide two 12m, 40-seater battery-powered buses, which will be fitted with autonomous driving technologies. ST PHOTO: TIMOTHY DAVID

www.straitstimes.com 11. Jan-18

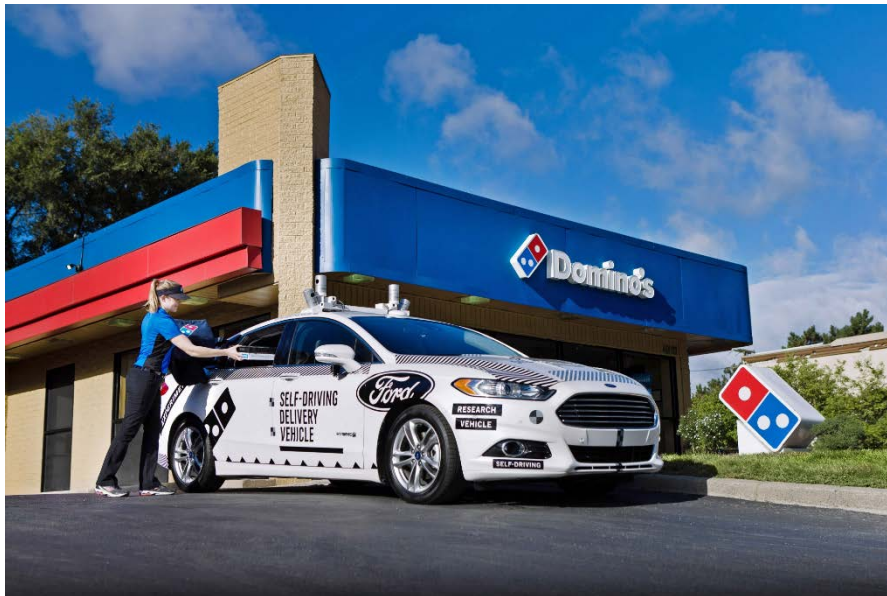
Automated trains

- Timing with regard to replacement of rolling stock
- Driverless S-trains;
 - Cheaper and more punctual operations
 - More frequent operations with little extra costs
- Driverless long distance and regional trains much further out in the future
- Changes will be less revolutionising than for driver less passenger cars



When we get completely autonomous cars!

- New use of cars
- New user groups
- Self-parking
- Easier Mobility as a Service
- Delivery transport by passenger cars



Disruption potential, driver costs

Mode	Share (%)
Passenger car	0
Taxi	73-77
Bus	67
Truck	33-40
Passenger train	25-27
Passenger airplane	10
Ship/ferry	3-70



Self driving trucks are already driving in closed areas



New use of cars

- Moving office
- Moving hotel room
- Assumably this will lead to (much) more transport



Microbe cars

- Require less area
- Special lanes
- Driving in emergency lanes?



New user groups

- Children
- Handicapped
- Elderly
- Drunk



Parking

- Empty drive waiting
 - No dis-benefit for the owner
 - VoT = zero
- Self driving to parking
 - Or empty return run

Average number
of persons per
car can be less
than 1



- Result

- Urban centres can be relieved for parked cars
- BUT the road network will be loaded with more congestion due to empty cars driving around
- And more car driving in general

Mobility as a service, empty driving

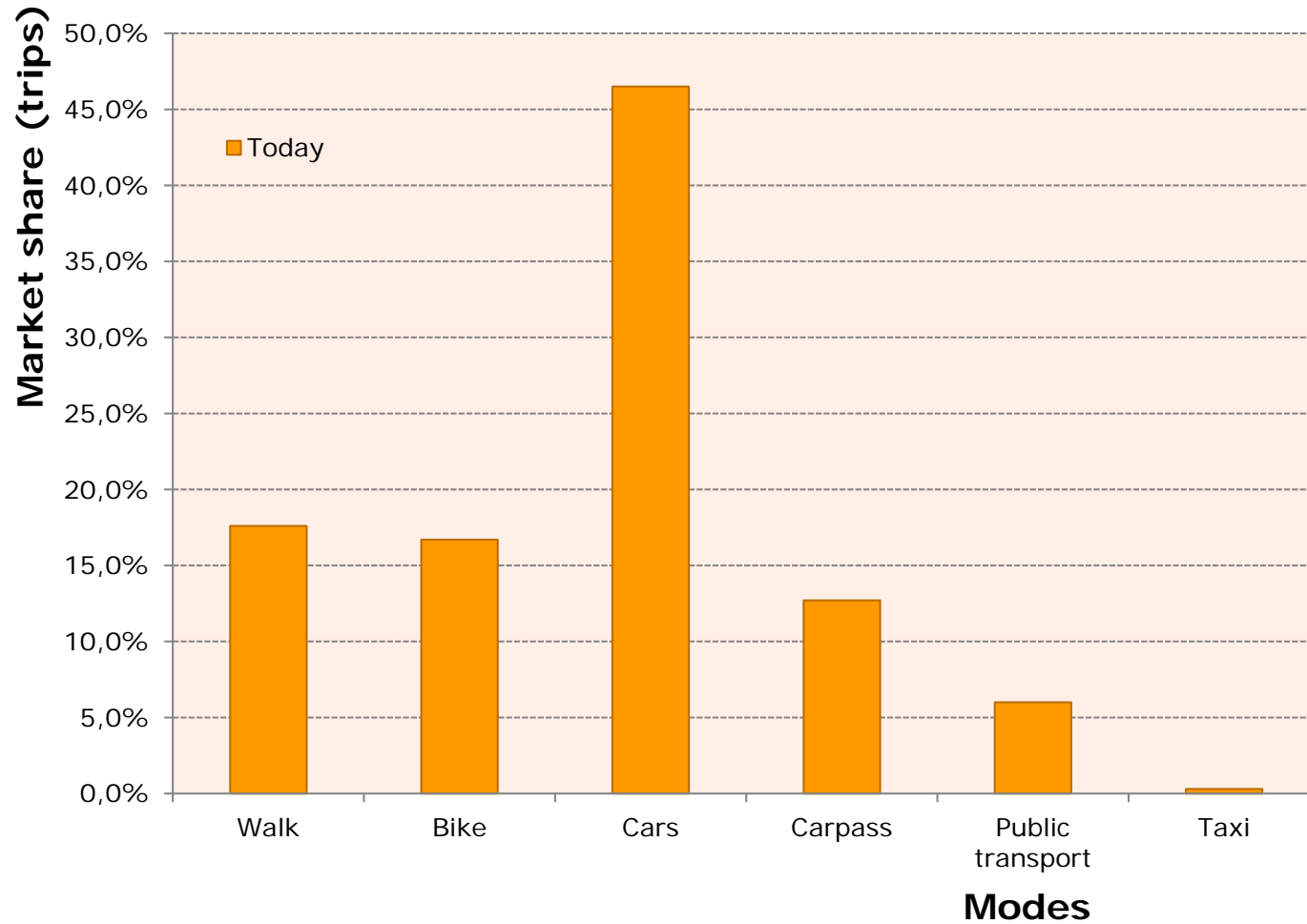
- Self driving cars solves the imbalance between flows of persons and goods in space and time
- Empty return run
- Repositioning of cars to expected demand
 - Swarm of cars driving around
- How Uber Uses Psychological Tricks to Push Its Drivers' Buttons
 - https://www.nytimes.com/interactive/2017/04/02/technology/uber-drivers-psychological-tricks.html?_r=0

Will autonomous MaaS cars replace private cars in the long run?

- MaaS becomes
 - Cheaper
 - Easier to use and more reliable
 - But still some transaction costs
- Private cars may become
 - Cheaper (relatively to income)
 - More flexible when autonomous
 - Still convenience of owning
 - And we become richer!

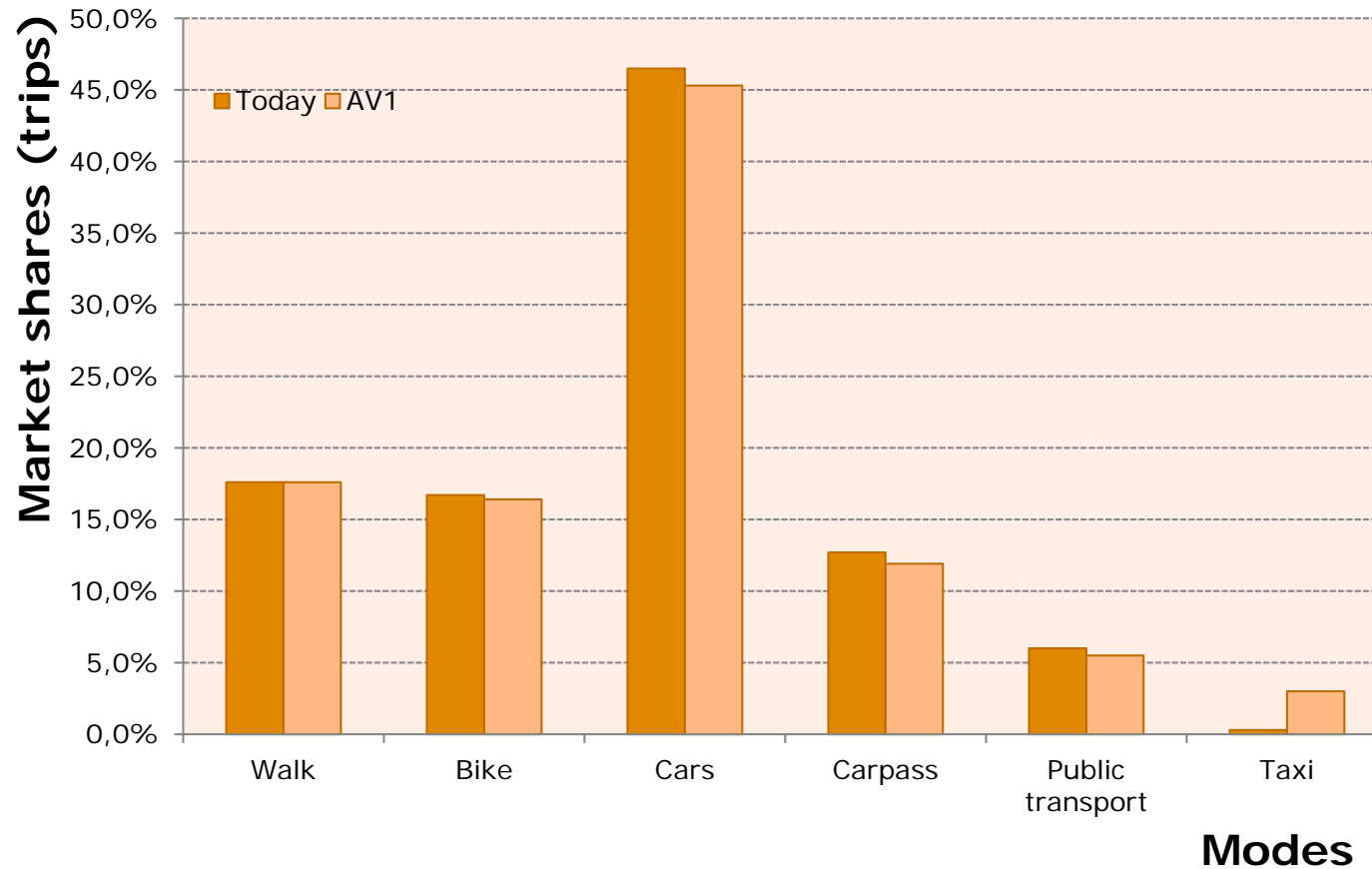


Market shared today



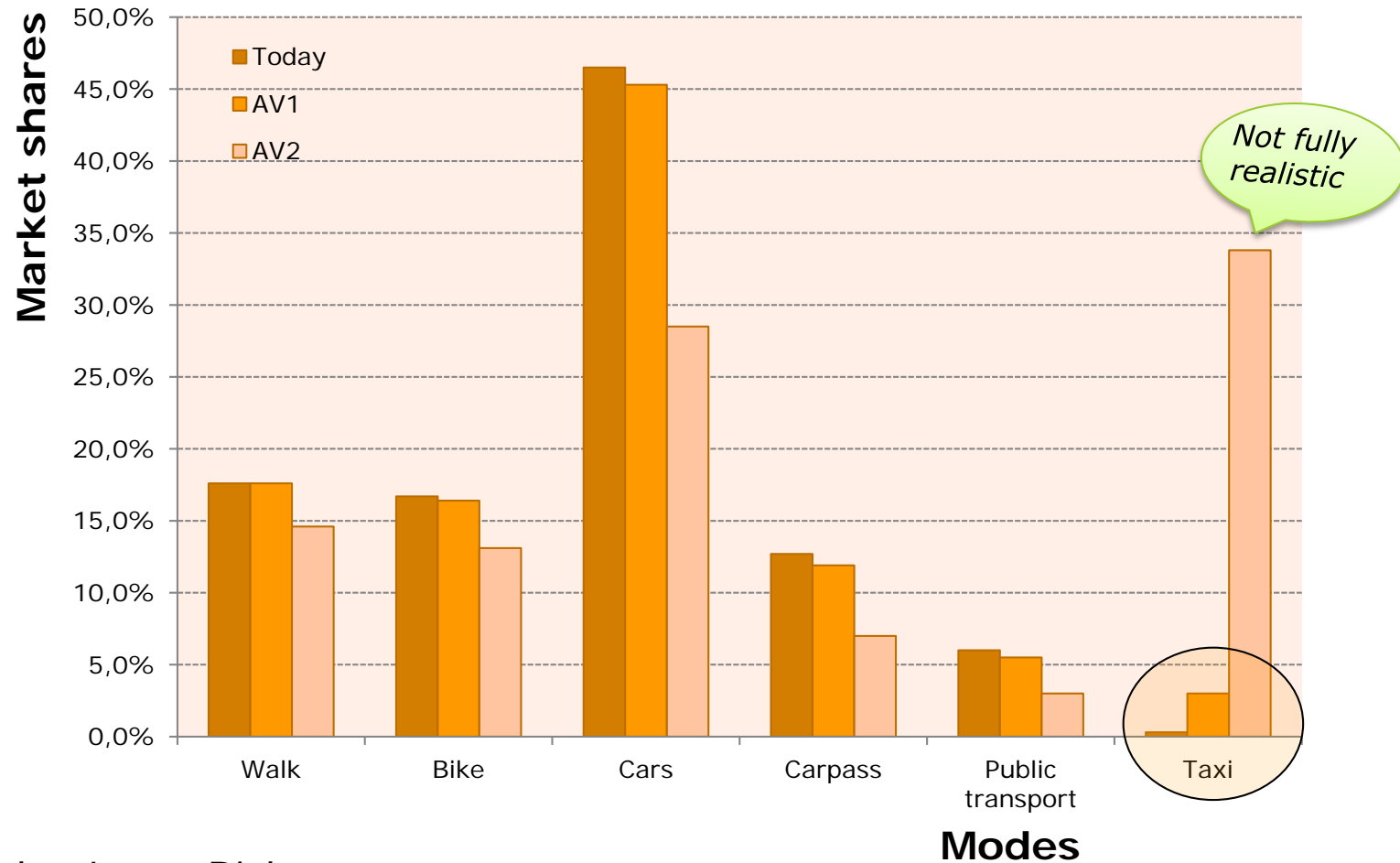
Source; Jeppe Rich

AV1: If taxis cost the same as one can expect from autonomous shared cars?



Kilde; Jeppe Rich

AV2: AV1 + all the flexibility as private cars can offer



Kilde; Jeppe Rich

Goods transport with autonomous "vehicles"

- Packages, letters, etc.
- Challenge mail and delivery firms
- Delivery robots "ground drones"



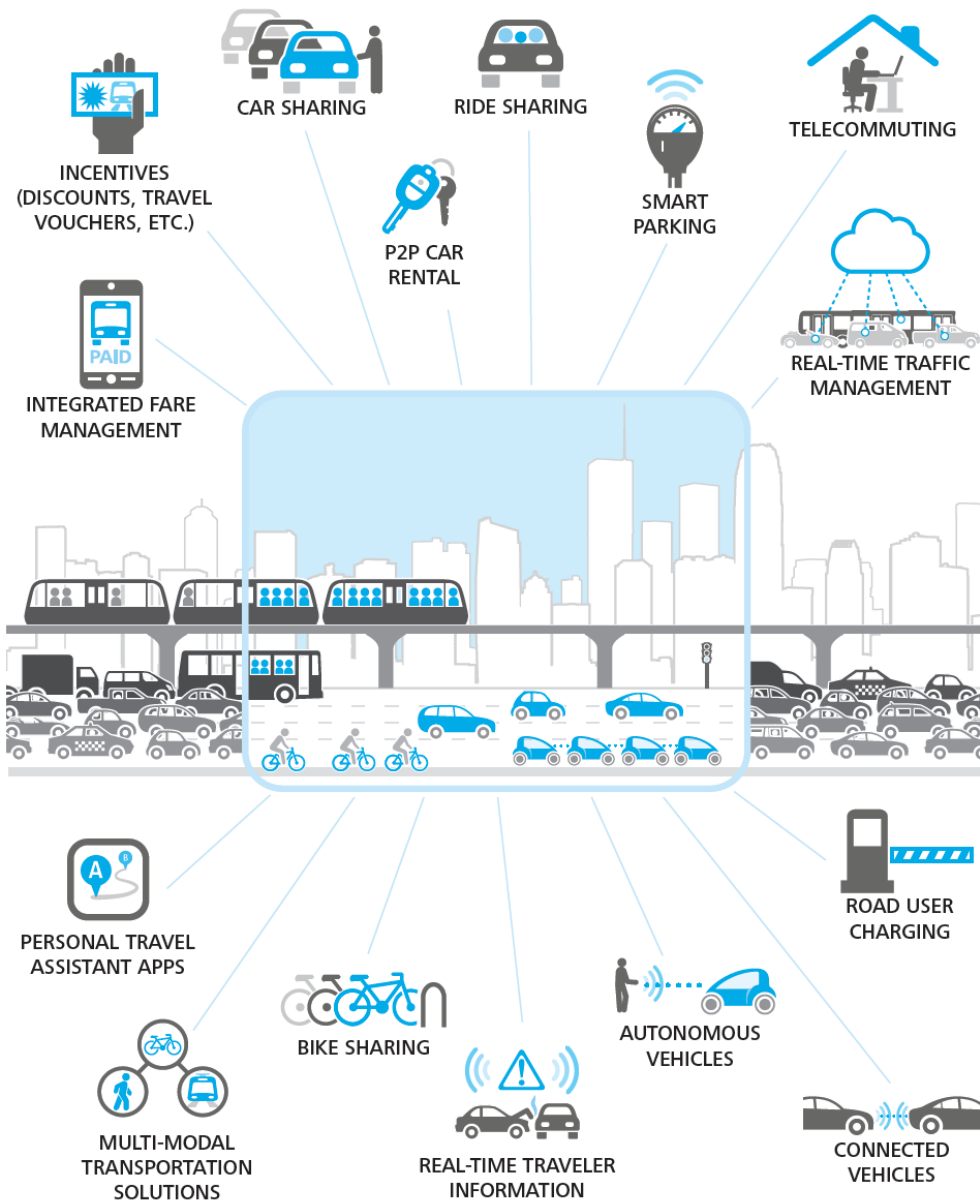
© Starship Technologies

DOMINO'S PIZZA JUST UPPED THEIR GAME WITH A GROUND DELIVERY DRONE

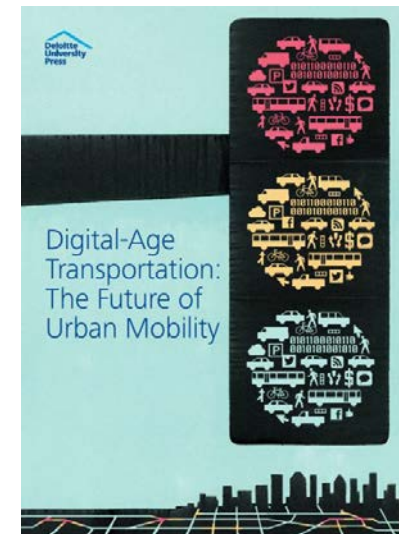


4 Digitalisation and connectivity





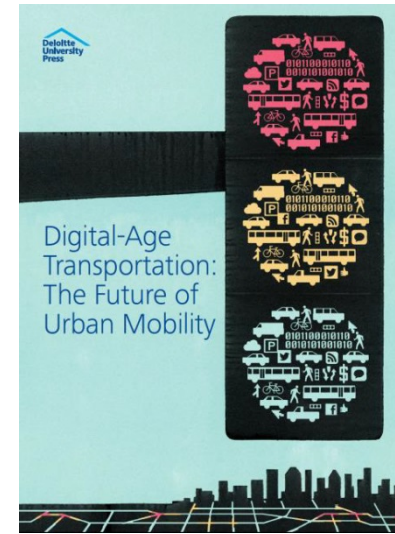
There's no silver bullet solution to the problem of gridlock – next generation urban transport systems will connect transportation modes, services, and technologies together in innovative new ways that pragmatically address a seemingly intractable problem



- http://www2.deloitte.com/content/dam/Deloitte/tr/Documents/public-sector/EN_Digital-Age-TRANSPORTATION_16.07.2014.pdf

Smart mobility visions

- The result of these innovations—and of the ecosystem of creative players that have been drawn to transportation, from information technology companies to ridesharing pioneers to app makers—is that the mobility field will look very different going forward. It will be:
- **Massively networked**, with ubiquitous connectivity throughout the system
- **Dynamically priced**, so as to balance supply and demand
- **User centred**, taking into account users' needs, priorities, data flows, and dynamic responses to conditions
- **Integrated**, so that users can move easily from point A to point B, regardless of mode, service provider, or time of day
- **Reliant on new models of private-public collaboration**, which take advantage of the increasingly diverse ecosystem of public, private, and non-profit entities that are working to meet the mobility challenges of the 21st century



Geographic dimension



Between cities



Between cities – motorways

- Self driving cars appears first on motorways
- Not necessary a safety benefit
- Comfort becomes (even) more important
- Extra lanes and LKA can increase the capacity within the same road profile
- Traffic growth probably larger than this capacity gain
- Graduate introduction



Between cities – railways

- Benefits for railways will be smaller, challenged by
 - Shared driving with passenger cars
 - Self driving cars, particularly by people who likes to work during the trip
 - Cheap driverless busses
- Long distance trains strength: High speed
 - Stopping patterns
 - Main lines vs. other lines
 - Electrification of side lines → Battery trains

Other cities and rural areas



Other cities and rural areas – shared driving

- Shared driving are today mainly long distance between large cities in East and West Denmark
- Great potential in shared driving: Could increase the mobility for persons without car access outside the larger cities and at times, when the public transport supply is weak
- Rules for allowed payment is however a barrier for short and medium-long trips

Other cities and rural areas – driverless cars

- Driverless cars may increase the mobility for kids and young and others without driving license and/or car access



Increased traffic and congestion not an issue



Foto: Movia, Fotograf Ulrik Jantzen

Other cities and rural areas – public transport



Driverless cars and new business concepts like flex-traffic (dial-a-ride)

→ Less need for traditional public transport

Public service obligation via driverless flex-concepts

The largest cities



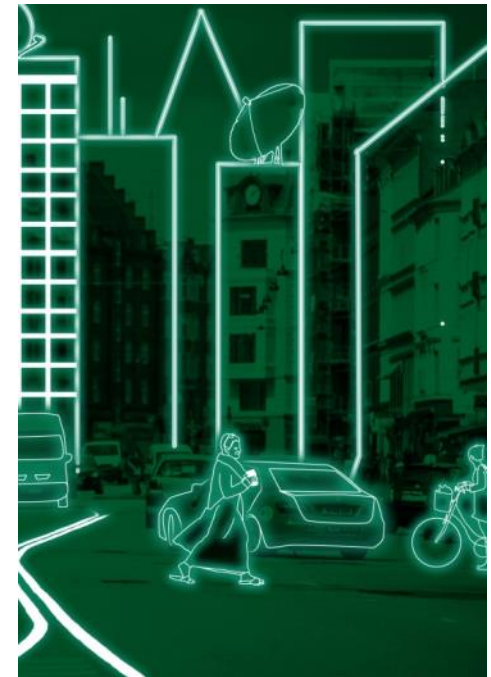
The largest cities' characteristics;

- High and increasing population density
- Public transport, bicycle and walk are the most important parts of the transport system, and congestion is a crucial problem
- Space is limited and areas for parking a special challenge

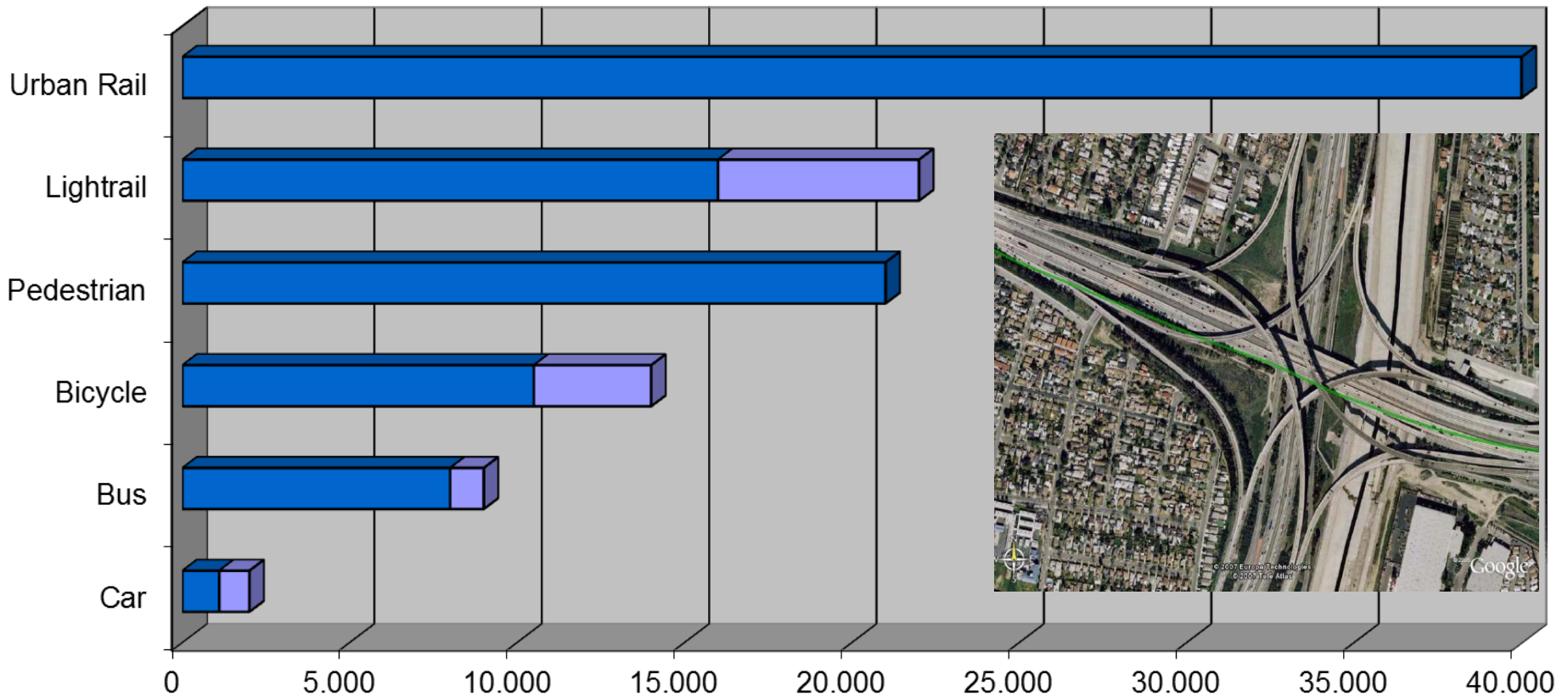


The largest cities – battle for space

- High level public transport and bicycling becomes even more important for mobility
- Especially in the Capital Region: Rail borne transport can relief the road network
- Shared cars increase mobility. Three types: Peer to peer, floating cars, shared cars with fixed parking location
- Shared cars do not necessary reduce traffic and congestion, but may reduce the need for parking



Capacity for different modes of transport (Passengers per hour per lane)



The largest cities– Mobility As a Service

MaaS is ideally a subscription, in which public transport is a key-component, which is supplemented by alternatives like shared cars, shared driving, taxi and city bicycles

- Potential: Better mobility concept for the users
- Can make some to drop the car
- The challenges:
 - Organisational and economic set-up
 - Real time information
 - Does it matter?

The largest cities – private cars or taxi concepts?

- Driverless taxis and shared concepts can become a real alternative to private cars depending upon costs and amount of weekend trips
- The economic incentive can be increased through change of rules and regulations, which makes larger payment for shared driving on short trips possible
- Less need for parking spaces

Influence on the city and urban quality

- Possibility to change parking places to other urban activities
- Shared cars might be electrical from the beginning
- Increase of traffic and congestion – also with shared and/or driverless concepts – maybe even more than without



Foto: Troels Heien, Monoline

Ring cities (suburbs)



Suburbs – self driving cars

- Self driving cars in queue-driving at radial and ring roads



More car use for commuting



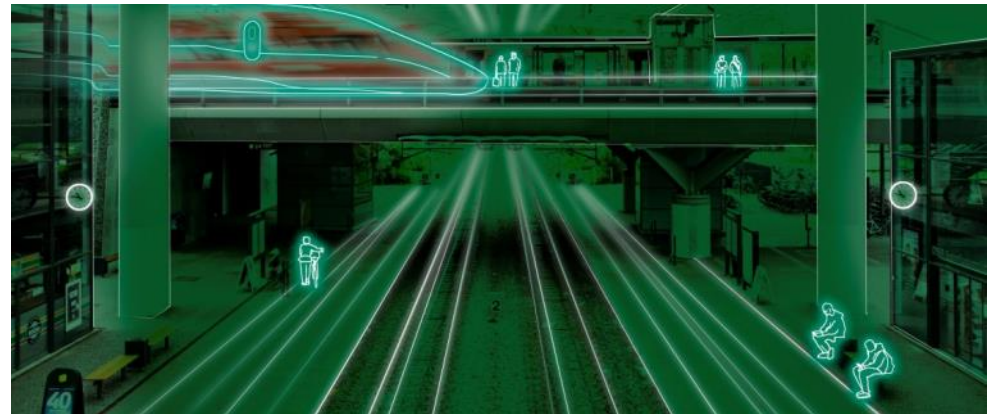
Suburbs – self driving busses

- Cost savings enables;
 - More lines
 - Lower marginal costs → higher frequency
- Automated BRT as an alternative to light rail

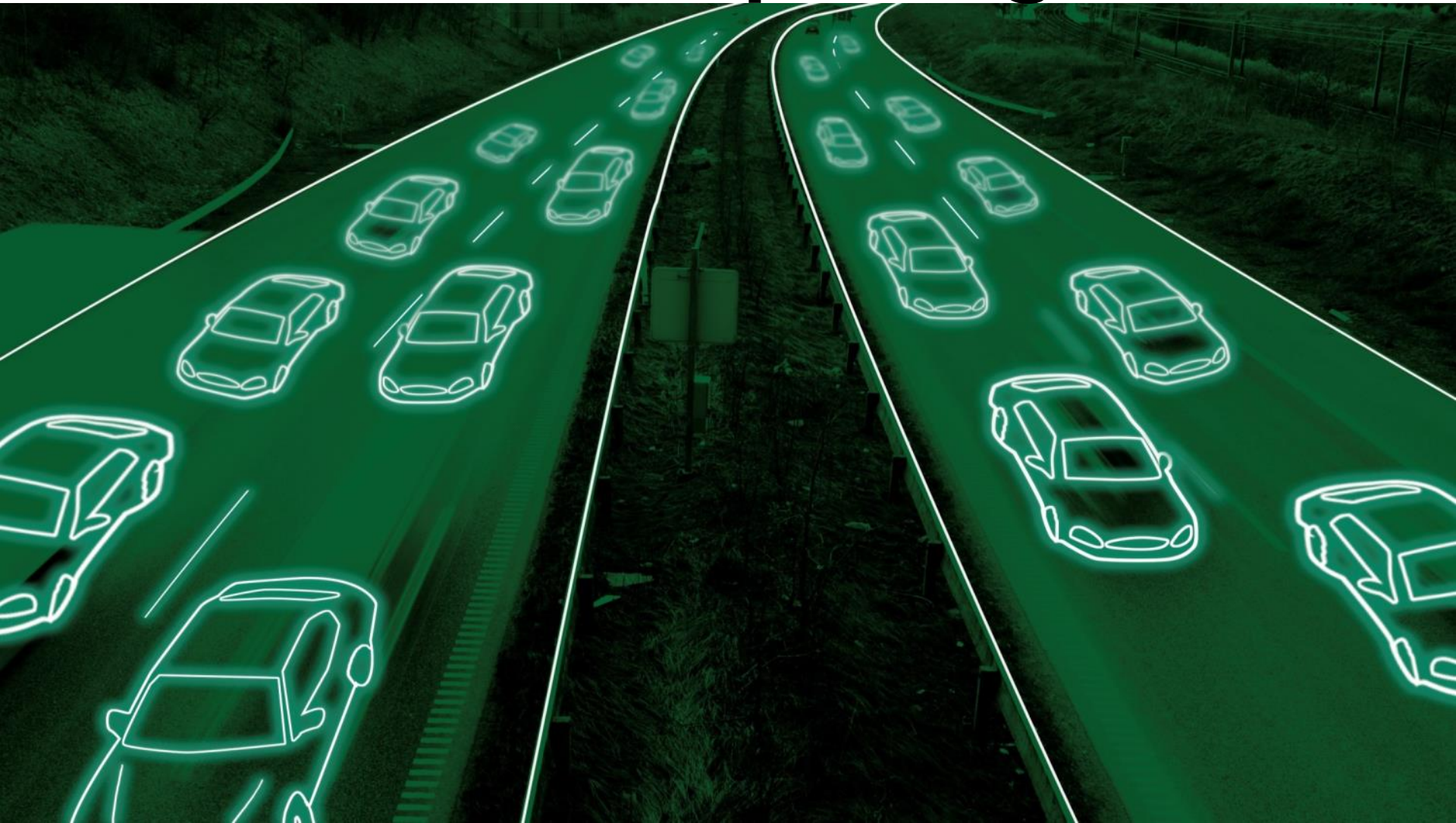


Suburbs – use of public transport

- Use of public transport depend on access to stations
- Driverless cars can increase the catchment area via 'kiss-and-ride'
- The car does not need to be parked at the station



Crosscutting insights and road pricing



Road pricing, dependent on time and location

- Benefits increases
- Costs decreases
- But still challenging to implement
- Does benefits justify the costs and risks?



Decision support

- CBA should be improved
 - When will automation and shared economy make a difference for projects that are realised today?
- The national transport model and other transport models should be developed further to consider
 - Self driving cars
 - Shared driving concepts

Modelling challenges

- New transport concepts
 - Some doesn't exist yet
 - Other have very low market shares and are still under critical mass
- More "modes" and mode chains as in traditional models
- Different degree on openness towards shared economy across generations
- Fleets of shared modes require new methods
 - Optimisation within modelling, as opposed to e.g. "traditional" public transport
 - Machine learning for short term demand prediction

Post script



And what happened with the expert group conclusion

Ole Birk: Sådan gør vi noget ved trængslen - Transportministeriet

Page 1 of 2

Ole Birk; This is how we can do something about congestion
More investments in roads, new technology and intelligent road pricing can in the long term keep congestion at a reasonable level



[Forside](#) / [Ministeren](#) / [Taler og artikler](#) / 2018 / Ole Birk: Sådan gør vi noget ved trængslen

The technology is still not good and robust enough to introduce time and space dependent road pricing, but it is only a matter of time before it will be a sufficient cheap and precise solution, which can replace the present car-related taxes, which are both too high and imprecise. If one instead of a high registration tax and high fuel taxes pay after how much on drive and contribute to congestion, then it will distribute the traffic both temporal and geographical. This will also increase the incentive to drive together in the rush hour and hereby utilise the car-fleet better

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Transport Summit DTU

31 May, 2018

- <https://transportsummitdtu.com/>
- No charge

