Summary

Transport Demand of the Future

Analysis and interpretation of societal trends and technological development

TØI Report 1723/2019
Author: Niels Buus Kristensen
Oslo 2019 57 pages Norwegian language

As input to the work with the next Norwegian National Transport Plan 2022-2033 TØI has made new projections of domestic passenger and freight transport (TØI report 1723/2019). The projections are based on the development of a number of factors that are uncertain by definition. This report analyses and interpret the importance of several societal and technological trends for transport demand and its distribution on the various modes of transport towards 2050.

The effects of economic and population growth as well as demographic changes and geographical population movements on transport demand are quantified. The calculations indicate that population growth is a pivotal factor behind expected transport demand and that uncertainties with regard to future economic growth have significant importance for level of transport volumes in 2050. Geographical population movements will increase urban transport demand but will only have limited impact on aggregate national level. An ageing population will per se reduce transport demand but uncertainty about lifestyle and travel behavioral changes compared to today's elderly might offset this effect. The consequences for the share of electric vehicles of political targets for greenhouse gas reductions and electrification is illustrated by projections from TØI-report 1689/2019.

The development speed of the two trends automation and shared economy and their impact on transport demands and capacity of the transport infrastructure are also important factors of uncertainty. The analysis is here more qualitative because their impacts are very difficult to quantify. The advantages will probably be biggest for road transport and lead to more car traffic and less use of public transport. Without intensified regulation this will expectedly strongly reinforce the tendency to more congestion in and around the major cities. Finally, five alternative future scenarios with full automation and shared mobility are described.

The transport sector faces a period where technological change is expected to lead to bigger changes of the transport system than what we have been used to. Radical changed features of the means of transport, new business models and intensified use of intelligent communication technologies as well as several long-termed societal trends will significantly influence how much, how and where we will travel and move freight in the future.

This report analyses the consequences of these technological changes and societal trends with a particular focus on examining:

- how and how much these can be expected to influence the need for infrastructure development within road, rail, sea and air transport.
- to what extent this need depends on the substantial uncertainties relating to future development.

The expected lifetime of infrastructure investments is long; technically often more than a hundred years. A hundred years from now technological development will have changed the transport sector radically and societal trends will have resulted in big changes in where we live and where and how much we travel. The economic lifetime, that is the time horizon with significant benefits for the infrastructure users, can therefore be much shorter. Cost-benefit analyses takes this into account to some extent by only counting user benefits for a shorter period (typical 40 years). But even within this shorter time horizon the benefits and costs can change significantly and therefore be very uncertain because we do not know what the future will look like.

Societal trends that will affect the total transport demand

Key drivers for future transport demand will be economic growth, population growth, ageing and urbanization. Long distance travel is expected to increase by about 35% towards 2050. Car will also in the future be the dominant mode of passenger transport and is expected to have an increasing market share. Walking and biking accounts for about one fourth of the trips but only an insignificant share of the travelled kilometers. Public transport is clearly most used in and around the major cities, while aviation has a much higher share in remote, rural areas.

Economic growth

Table S.1 shows the importance of the assumptions made about future economic growth for long distance travel.

Table S.1 Estimated development in passenger kilometres for long distance travel under alternative assumptions about economic growth. 2018 = 100.

	Reference 2050	High growth 2050	Low growth 2050
Yearly growth in private consumption per capita	1.45%	1.94%	0.00%
Passenger-km in 2050 (2018=100)	**135**	**145**	**120**

Source: Tabell 2.2.

With the reference assumption of an average yearly growth per capita of 1.45%, calculations with the national transport model indicates that total passenger kilometres will increase by 35% towards 2050. With high (≅2% per year) and no growth assumptions the figures are 45% and 20% respectively for the same period. If the model adequately reflects the relation on economic growth, it shows how the economic growth is of great significance for how fast long-distance travel will grow.

Demographic changes

Significant demographic changes are expected over the next 20-30 years:

- *Population growth*: By 2040 the Norwegian population is expected to be about 16% higher, primarily due to immigration and decreasing mortality rates.
- *Ageing*: Most of the population growth will appear as a significantly increased proportion of elderly above 65 years and an increased proportion of children and youth.
- *Urbanization*: Movements to the urban areas and especially from town to the major cities have taken place in the last hundred years and is expected to continue in the future.

Table S.2 shows estimations of the effect on total passenger kilometres for each of these trends. The calculations are based on the population projections from Statistics Norway and the Norwegian Travel Survey (RVU) 2013/14, under the assumption that the population's travel patterns will not change towards 2040 compared to RVU 2013/14.

Table S.2 Total daily travel demand in 2040 (2018 =100) by travel purpose. Assuming unchanged travel patterns within groups.

Travel purpose:	All	Work and school	Business	Private
Main alternative (MMMM)				
Population growth	116	116	116	116
Population growth + changed age composition	111	106	107	114
Population growth + changed age composition + movements between municipalities	110	105	106	113

Source: Tabell 2.6.

Looking only at population growth, it will by assumption result in the same transport growth with unchanged transport patterns, that is a 16% increase by 2040. Taking into account that the elderly and young people travel shorter distances, the demographic changes across age groups will reduce the growth by 5 %-points to 11%. As expected, the reduction is biggest for work- and school-related trips. If we additionally take into account that people will be more inclined to live in (larger) urban areas where the travel distances are shorter, the growth will be reduced by another 1%-point.

Changed travel behaviour?

The assumption of unchanged travel behaviour is of course a strong simplification. But it serves to illustrate the isolated effects of each of the trends; that there will be more of us, we will become older and will live more and more in cities. However, there can, in particular, be a reason to look more into the expected travel behavior of the upcoming older generations as other societal trends drives this group towards more travel activities than people within these age groups today:

- *Better health* means that you will have better possibilities to maintain high mobility later in life.
- *Postponed retirement* will result in an increased number of commuting trips.
- *Generation effects* will increase travel activity: A 40-year old person travels more than a person at same age 20 years ago. A part of this difference is related to life style changes that he or she probably will maintain later in life.
- *Gender equality*: Men above 70 travel on average significantly longer for everyday private trips than women of the same age, but this not the case for age groups below 60.

It is difficult to estimate how these lifestyle changes will affect travel demand decades from now. However, a calculation with stylized assumptions can give an idea of the order of magnitude of the effect compared to the trends analysed in Table S.2. The calculations indicate that the four lifestyle changes above can potentially more than outweigh the impacts from the demographic changes in Table S.2.

Consequences of the global warming challenge

Based on the huge challenges related to global warming the Norwegian Government has declared it will strive to make Norway a low-emission society with a 90-95% cut in greenhouse gas emissions in 2050 and halve emissions from transport in 2030 compared to 2005[2]. Transport sector emissions account for 30% of today's emissions and the share is increasing. This level of ambition implies that almost all land transport has to be emission free in 2050 supplemented by substantial cuts in emissions from aviation.

Railway transport

The railways in Norway are already today practically emission free because of electric propulsion on most railway lines and a power production dominated by renewable energy sources. Today this gives the train a clear environmental advantage compared both the private car and air transport.

Road transport

Road transport is by far responsible for the majority of transport related CO_2 emissions. For *passenger cars* the technological development of electric vehicles has been so rapid that full transition to battery electric propulsion appears to be practically feasible within few years. The targets in the current *National Transport Plan 2018-2029* states that all new cars sold from 2025 will be zero-emission vehicles. From 2030 the same will apply for vans (as well as for 75% of long-distance busses). This means that as the vehicle fleet is replaced, most light-duty vehicle traffic will be without global warming emissions in about 20 years.

Implementing technical solutions that can drastically reduce emissions from *heavy goods road transport* are much more challenging, especially for long distances. We cannot say with reasonable certainty which the future zero-emission propulsion systems for long distance vehicles for heavy goods will be. There are several technological options, for example:

- Electrification in combination with
  - battery
  - fuel cell and synthetic fuel, e.g. hydrogen
  - overhead catenaries supplemented by small batteries for the first/last mile
- Combustion engine in combination with
  - synthetic fuels, including hydrogen, as energy carrier, produced from renewable energy based power
  - biofuels, possibly in combination with synthetic fuels

Today, these alternatives are either not ready for implementation, costly or with dubious sustainability in full scale implementation. In addition, strategic national choice of technology is complicated because of the fact that it will have to be in line with technology development in the rest of Europe where vehicle production takes place.

However, technological solutions that can transform the propulsion system of heavy goods vehicles towards renewable energy is a necessity. This is because a shift of freight from road to rail or sea, to the extent necessary to achieve the reduction targets, is not realistic.

An important consequence of the necessity of road transport being practically emission free in the future is that the train's global warming advantage will vanish, and climate policy will no longer be an argument for the 'zero-growth target' for car traffic in the major urban areas or for the 'shifting freight from road to rail and sea' strategy.

---

[2] Politisk plattform for en regjering utgått av Høyre, Fremskrittspartiet, Venstre og Kristelig Folkeparti den 17. januar 2019 [https://www.regjeringen.no/no/dokumenter/politisk-plattform/id2626036/].

Air transport

Civil aviation accounts for about 7% of the greenhouse gas emissions from Norwegian domestic transport and from international routes. Flight travel is expected to increase significantly in the future which makes measures to reduce emissions from air travel increasingly important. Over the past two decades CO_2 emissions per passenger kilometer has been reduced to the same order of magnitude as for cars. But the global warming effect from aircraft emissions are stronger when they occur at high altitudes. In addition, the high travel speed of airplanes is in itself a problematic factor from a CO2 emission perspective because it possible to travel to very far away destinations resulting in high emissions per trip. Sustainable biofuels or synthetic fuels are feasible technical options for significant emission reductions, but their use is insignificant at present. Substantial research is ongoing to develop electric propulsion for aircraft, but even if successful, it will at best contribute significantly to emission reductions beyond 2030.

Ferries and sea transport

Sea transport is also only in the very initial phase of a transformation to zero-emission technology. The transformation may over time increase energy costs and hence increase transport costs for both seaborne freight and road connecting ferries across the fjords. But it will probably not be to an extent which will have substantial influence on transport demand.

New technologies and business models

Cooperating intelligent transport systems

The roll-out of 5G telecommunication will dramatically increase reliability, speed and capacity of wireless data transmission. This is expected to increase the potential of Co-operating intelligent transport systems C-ITS by enabling vehicle-to-vehicle and vehicle-to-infrastructure connectivity for real-time exchange of relevant data on position, speed, direction and weather conditions. C-ITS is expected to provide significant societal benefits in terms of better traffic flows and increased road capacity as well as traffic safety improvements, fuel savings and lower emissions.

Automation

Technology for automation of road transport has advanced rapidly over the last ten years, but the time horizon for offering practical use in Norway is still very uncertain. At the same time there is little doubt that automated cars will have wide-raging impacts on transport demand and the transport system, even though it is difficult to predict how much and to what extent it will change our choice of mode of transport. These uncertainties give rise to correspondingly high risks for mistakes in infrastructure investments.

Automation is best considered as a continuum of gradually less human involvement in the driving process. From a user and transport behaviour perspective two levels can in the future result in decisive changes compared to today, related to the need for a driver:

Self-driving vehicles with a human in the driver's seat: The car (or the bus, train, ferry or airplane) is capable of driving safely without human interference but a human 'back-up' has to be on stand-by and ready to take over with short notice on request from the car when unexpected situations occasionally occur. The expected direct societal benefits are especially:

– *Enhanced traffic safety by avoiding human errors*. Inattention, speeding, overlooking other road users and other driver related risk factors are the most important causal effects for traffic accidents.
– *The driver can utilize travel time for something more useful.* Spending time driving will therefore be less disadvantageous.

Both effects are most important for private car use compared to other modes, because professional drives must be paid anyway. This type of automation will probably be easiest to implement on motorways and most difficult to implement in urban traffic and under bad weather conditions.

The generalized travel costs for private cars will diminish, leading to an increase in demand for car driving and attracting trips from other modes, including public transport. Higher value will be attached to comfortable driving as it makes travel time more useful. This may impact road design and maintenance, e.g. road curvature and pavement quality. Traffic capacity may also increase for some roads if lane width and safety distances between automated cars can be reduced.

Driverless vehicles: Safe door-to-door transport without a driver onboard. A crucial impact is that it will also be possible to reposition empty vehicles. Full automation appears to be extremely difficult, so what we may see first is driverless driving confined to a certain area (geofencing) or road type or conditional of weather condition etc. Driverless cars will give rise to distinctly new possibilities:

– *New user groups of private cars.* People without a driver license can use a car, e.g. children and elders, who are now dependent on public transport or on others to give them a ride. Similarly, you can get things carried from one place to another without having to spend your own or a driver's time getting it done.
– *Higher utilization rate by empty repositioning.* Today private cars stand still while the user stays at the destination. If the car can drive home by itself the rest of the family can use it, while parents are at work. This means that the actual car access is increased in households with both one and two cars.

These new opportunities for car use will most likely significantly amplify impacts of self-driving cars with a human in the driver's seat in terms of an increased demand for car driving and less demand for public transport.

In general, automation will only slowly penetrate the car fleet, partly because it will take many years from introduction to full market share among new car sales, and partly because private cars typically last far more than ten years.

Automation of trucks is primarily relevant as driverless vehicles. You can save costs for the driver, which constitute of about a half of the total costs per truck kilometer. Automated long distance road haulage does not have to be door-to-door but could be between distribution terminals or specially designed logistics centres with own exits at motorways outside cities, where chauffeurs take over the first/last mile driving. The strong commercial potential from the saved driver costs might drive automation to faster implementation for trucks than for private cars.

Within **air, rail and sea transport** automation can potentially reduce operational costs and increase infrastructure capacity, but the driver's share of total costs will be far less compared to road transport which indicates that price reductions and thereby much smaller demand effects in general.

Shared mobility

New shared mobility solutions are growing rapidly, but their share of total transport volumes is still limited. The potential for shared mobility solutions is biggest in cities for logistic reasons. Car sharing can be considered as an alternative to a private car or an alternative to a second car in the household. It can, on the other hand, increase car access for those who cannot afford a car or for those not needing an own car. It is not clear whether widespread car sharing will lead to more or less car traffic. But an important impact will be a decreased demand for parking lots, which is especially important in cities, where space is scarce and there are other valuable alternative uses of parking areas that benefit urban life. Prices on parking reflecting this value can be a cost-effective instrument to promote car sharing and thereby optimizing the use of urban space.

Automated shared mobility concepts

When comparing car sharing to owning a private car a main disadvantage is that you have to walk to the car, which will typically not be parked at your front door. Taxis solve this problem for you and drive you door-to-door, as do Uber/Lyft-concepts that have taken over dominant market shares in many big US cities. Within a few years these platform-based concepts expect to start using driverless cars, also called '*Robotaxis*'. The time horizon for commercial roll-out, as well as which countries and cities they will be operating in, is currently very uncertain.

However, it seems fair to conclude that:

- Robotaxis could give big mobility improvements for people not having access to use a car today. The need for parking space in city centres could be reduced significantly to the extent that robotaxis could replace inhabitants' private cars.
- Empty driving, detours, shifts from public transport and increased transport demand will result in significant increased car traffic up to a level that without stricter regulation would lead to unsustainable congestion and travel time delays.
- Integrating robotaxis in mass transit transportation systems, especially as a 'first/last-mile' service, could improve public transport and potentially increase ridership in and around major cities.

Scenarios for automation and shard mobility in future transportation

The figure below presents an overview of five scenarios for future electrified, fully automated road transport in urban areas with different degrees of shared solutions.

Scenario Characteristics	(1) Automated cars for all Unrestricted private cars use	(2) Curbed congestion Private cars and capacity pricing	(3) Robotaxis Car trips on demand	(4) Microtransit Shared rides on demand	(5) Mass Public Transit First/last mile by micromobility
Ownership	Private	Private	Private / (Public)	(Private) / Public	Public
Use	Individual	Individual	Individual / (Shared)	(Individual) / Shared	Shared
Regulation (example)	None	Road capacity pricing	Parking pricing	Access restrictions	Public utility
Traffic & congestion	Intensive	Significant	Significant	Less	None
No.of cars & parking needs	High	Significant	Limited	Small	None

The scenarios span over three different dimensions:

Private ↔ Public
Individual ↔ Shared
Unregulated ↔ Regulated

which in practice will correlate. The five scenarios are described below to highlight the differences. But reality could rather be seen as a mixture with varying weight on each scenario.

1. *Automated Cars for All.* New possibilities with driverless, private cars will result in significantly higher demand for car use, which without strong regulation will lead to very substantial traffic growth. In city centres this will cause severe congestion problems which will limit mobility in these areas. Outside densely populated areas people without a driver's license can obtain substantial mobility advantages by car use compared to dependency on other modes.

2. *Curbed Congestion.* This scenario can be seen as an active regulatory reaction to the traffic challenges by the previous scenario's unconstrained individual use of automated cars. Cooperative intelligent communication technology will facilitate the use of dynamic road pricing as a regulatory measure where severe congestion reduces mobility. Such a system will have clear advantages in terms of efficiency and fairness compared to the toll rings used today in Norway primarily for financial purposes.

3. *Robotaxis.* On-demand driveless taxis with high capacity utilisation and no costs to a driver might make this concept an attractive alternative to owning a car, especially in big cities where there is less need for a car and the costs and troubles related to parking are substantial. Widespread abandoning of private cars will not necessarily result in less driving and congestion than in the previous private car scenarios. The main advantage will be a by far smaller vehicle fleet that will need dramatically smaller area for parking spaces in cities, where space is scarce.

4. *Microtransit.* For car sharing and robotaxis to give less car traffic and congestion they will require a higher occupancy rate. This can be achieved by sharing the ride with others, who are not necessarily going from the same origin to the same destination. It also implies accepting a bit longer travel time connected with a detour. On the other hand, the price will also be shared, but perhaps the savings will not be enough to make us share the ride with strangers. Road pricing at a level that will significantly reduce congestion can amplify the incentives to develop and use ride-sharing concepts because the price per passenger will be much less with more people in the vehicle. In less densely populated areas and between cities shared on-demand services can serve as individualized alternative to traditional public transport.

5. *Mass Transit.* The focus of this scenario is primarily on the biggest cities' challenges with securing mobility by diminishing congestion. Conventional public transport concepts with high capacity seem to be a necessary part of a well-functioning transport system in a big city, irrespectively of the advent of automated and individualized, shared mobility concepts. Full automation of metro, tram and bus can reduce costs and improve operations and can, particularly for buses, give high frequencies in off-peak at low marginal costs. App-based micromobility concepts can be integrated in the public transport as part of first/last mile transport to develop create *Mobility-as-a-Service* solutions.

The balance between the advantages and disadvantages of the different modes of transport is closely related to the degree of urbanisation and trip length. This will also be the case in a future with autonomous vehicles and shared mobility. The bigger the city and the higher the population density, the more advantageous will the scenarios in the right-hand side of the figure be and vice versa.