International Transport Forum

Reallocation of Road and Street Space in Oslo

Measures for Zero Growth in Urban Traffic

181 Roundtable

Discussion Paper

Aud Tennøy
Norwegian Centre for Transport Research, Oslo

Oddrun Helen Hagen
Norwegian Centre for Transport Research, Oslo

Reallocation of Road and Street Space in Oslo
Measures for Zero Growth in Urban Traffic

181 Roundtable

Aud Tennøy
Norwegian Centre for Transport Research, Oslo

Oddrun Helen Hagen
Norwegian Centre for Transport Research, Oslo

Discussion Paper

The International Transport Forum

The International Transport Forum is an intergovernmental organisation with 62 member countries. It acts as a think tank for transport policy and organises the Annual Summit of transport ministers. ITF is the only global body that covers all transport modes. The ITF is politically autonomous and administratively integrated with the OECD.

The ITF works for transport policies that improve peoples' lives. Our mission is to foster a deeper understanding of the role of transport in economic growth, environmental sustainability and social inclusion and to raise the public profile of transport policy.

The ITF organises global dialogue for better transport. We act as a platform for discussion and pre-negotiation of policy issues across all transport modes. We analyse trends, share knowledge and promote exchange among transport decision-makers and civil society. The ITF's Annual Summit is the world's largest gathering of transport ministers and the leading global platform for dialogue on transport policy.

The Members of the Forum are: Albania, Armenia, Argentina, Australia, Austria, Azerbaijan, Belarus, Belgium, Bosnia and Herzegovina, Bulgaria, Canada, Chile, China (People's Republic of), Croatia, Czech Republic, Denmark, Estonia, Finland, France, Georgia, Germany, Greece, Hungary, Iceland, India, Ireland, Israel, Italy, Japan, Kazakhstan, Korea, Latvia, Liechtenstein, Lithuania, Luxembourg, Malta, Mexico, Republic of Moldova, Mongolia, Montenegro, Morocco, the Netherlands, New Zealand, North Macedonia, Norway, Poland, Portugal, Romania, Russian Federation, Serbia, Slovak Republic, Slovenia, Spain, Sweden, Switzerland, Tunisia, Turkey, Ukraine, the United Arab Emirates, the United Kingdom, the United States and Uzbekistan.

International Transport Forum
2 rue André Pascal
F-75775 Paris Cedex 16
contact@itf-oecd.org
www.itf-oecd.org

ITF Discussion Papers

ITF Discussion Papers make economic research, commissioned or carried out in-house at ITF, available to researchers and practitioners. They describe preliminary results or research in progress by the author(s) and are published to stimulate discussion on a broad range of issues on which the ITF works. Any findings, interpretations and conclusions expressed herein are those of the authors and do not necessarily reflect the views of the International Transport Forum or the OECD. Neither the OECD, ITF nor the authors guarantee the accuracy of any data or other information contained in this publication and accept no responsibility whatsoever for any consequence of their use. This document and any map included herein are without prejudice to the status of or sovereignty over any territory, to the delimitation of international frontiers and boundaries and to the name of any territory, city or area. Comments on Discussion Papers are welcome.

Cite this work as: Tennøy, A. and O. Hagen (2020), "Reallocation of Road and Street Space in Oslo: Measures for Zero Growth in Urban Traffic", *International Transport Forum Discussion Papers*, No. 2020/14, OECD Publishing, Paris.

Acknowledgements

The authors are grateful to the BYTRANS project team and the research group Sustainable Urban Development and Mobility at the Institute for Transport Economics for fruitful discussions and joint research on the zero-growth objective and the effects and consequences of reallocating road and street space to other uses. They would like to thank the participants of the International Transport Forum (ITF) Roundtable on “Zero Car Growth? Managing Urban Traffic” for interesting discussions and helpful inputs, and Tatiana Samsonova of the ITF for inviting us to write the paper and for preparing and organising the Roundtable so well.

Table of contents

Introduction

Developing cities and urban transport systems in ways that ensures efficient mobility while reducing the environmental effects from the transport sector, is a challenge shared by many politicians, professionals and researchers across the globe. How to do this while making cities more attractive and vibrant, is an even greater challenge. Transport accounts for nearly a quarter of current greenhouse gas emissions, with passenger transport contributing to about 50% of total transport emissions in 2015 (IEA, 2017). In the absence of substantial reductions in vehicle kilometre travelled (VKT) per capita worldwide, increases in fuel-efficiency and the use of low-carbon fuels will only slow, not reverse, the rise in per capita CO_2 emissions (UN, 2013). In this context, reducing driving overall to scale back the environmental and social costs associated with private car use is necessary to meet sustainability objectives.

Since 2012, the Norwegian Government has promoted the zero-growth objective, stating that increasing passenger transport demand caused by the rapid population growth in the largest Norwegian urban regions shall not cause growth in passenger road-traffic volumes (total VKT in the urban region). The ultimate aims of the objective are more attractive, and more liveable, cities and urban regions that have more efficient mobility systems. This means active modes will constitute a larger share of transport, city centres will be vibrant and accessible, and the transport sector will generate less local and global pollution. A main strategy for achieving this is developing land-use and transport systems in directions that contribute to reduced transport demand, shorter trips and shifts in the modal split towards less car use. This requires multi-level and cross-sectoral coordination and steering, and is not an easy task.

Reallocating road and street space to uses other than driving and parking private cars seems like an obvious measure when aiming at shifting the relative competitiveness of sustainable modes of transport versus the car, and achieving zero-growth or reduction of traffic. It seems, however, that authorities' fear of negative effects and consequences is a key barrier for doing so. This was the key motivation behind the research project, BYTRANS: to investigate adaptations to, and effects and consequences of, planned, significant and relevant changes that would take place in the transport systems in Oslo in the period 2015-2020. The researchers understood the planned changes as natural experiments, offering great opportunities for investigation and knowledge production that could provide important and useful knowledge for authorities, and others, when developing more efficient and sustainable cities and urban transport systems for the future.

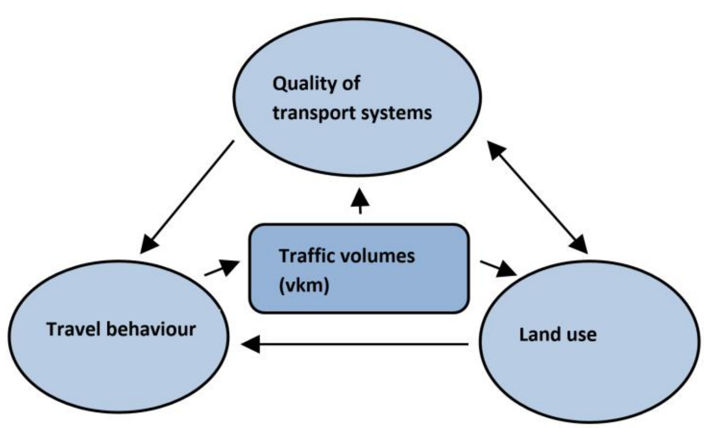
The paper first describes the Norwegian zero growth objective, followed by a discussion on how reallocation of road and street space to other uses might reduce car dependency and traffic volumes. Then follows a brief description of Oslo's urban region, and quite thorough descriptions of results from three of the cases studied in the BYTRANS project. These are two main road tunnels (with annual average daily traffic (AADT) of 50 000 and 70 000) where capacity was reduced from four to two lanes, due to rehabilitation works, for 12 and 14 months, and Oslo city centre where street space has been reallocated from parking and driving to other uses. Some findings concerning responses to other changes in the transport systems, as well as to the totality of changes, are also included. The final sections discusses the results, which closes with a reflection on whether Norwegian cities are steering towards zero-growth, and what the strongest barriers might be.

The Norwegian Zero-Growth Objective

The Norwegian zero-growth objective states that increasing passenger transport demand caused by the rapid population growth in Norwegian urban regions shall not cause growth in passenger road-traffic volumes (total VKT in the urban region). The goal was first stated in the Parliament's climate agreement (Ministry of Local Government and Modernisation, 2012), and later in two subsequent National Transport Plans (Ministry of Transport and Communications, 2013, 2017). Hence, two governments of different political parties have promoted the objective. As traffic growth and car-dependency in urban regions have multiple negative effects and consequences, the ultimate aims of working towards the zero growth objective are more attractive and liveable cities and urban regions. This includes vibrant and accessible city centres, and efficient, safe and convenient mobility systems. Active modes of transport should constitute a greater share of the transport system, in order to strengthen public health. The transport sector will generate less local and global pollution.

Achieving the zero-growth objective, as the population in the urban region grows, requires that inhabitants reduce their daily car traffic volume by making fewer trips on average, shorter trips and/or lower shares of trips as car drivers (Tennøy, 2012). A main strategy for achieving this is developing land-use and transport systems that contribute to reduced transport demand, shorter trips and shifts in the modal split towards less frequent car use (Ministry of Local Government and Modernisation 2015, Ministry of Transport and Communications, 2017). This strategy largely leans on theoretical and empirical knowledge concerning how and why the spatial structure (Hurlimann and March 2012; Newman and Kenworthy, 2015; Næss, 2012; Næss et al., 2019; Rode et al., 2017; Wolday et al., 2019), as well as absolute and relative qualities of the transport-systems (Börjesson et al., 2012; Cairns et al. 2001; Downs, 1962, 2004; Fishman et al., 2014; Goodwin, 1996; Litman, 2018; Noland and Lem, 2002; Tennøy et al., 2019a,2019b; Walker, 2012), affect travel behaviour and traffic volumes, as illustrated in Figure 1 (see Tennøy, 2012 or Tennøy et al., 2016 for further explanations).

Figure 1. Interrelations between land use, transport systems, travel behaviour and traffic volumes



Source: Based on Tennøy 2012 and Tennøy et al., 2016.

Hence, there is a relatively widespread agreement on how land-use and transport systems ought to be developed to reduce or limit urban road-traffic volumes: 1) land-use development as central, urban densification and transformation rather than sprawl; 2) improving conditions for walking and bicycling; 3) improving public transport services, and 4) physical and fiscal restrictions to regulate private car traffic (Downs, 2004; Banister, 2008; Newman and Kenworthy, 2015; Rode et al., 2017; Tennøy, 2012; Tennøy et al., 2016).

Steering land-use and transport systems developments in the direction of contributing to achieving the zero-growth objective requires national, regional and municipal authorities to work together, across relevant sectors. Steering is done through planning and decision processes under the Planning and Building Act (PBA) (Ministry of Local Government and Modernisation, 2008), through public planning, funding and implementation of transport infrastructure and public transport services, and use of fiscal measures like road-tolling and pricing of public parking.[1] Real and fundamental conflicts are embedded in land-use and transport planning; stakes may be high, and, while some actors will gain, others will lose whatever decision is made (Flyvbjerg, 1998). The planning processes can therefore be understood as multi-level and cross-sectoral arenas for battles, conflict resolution, priority-setting and decision-making, which does not necessarily mean arriving at a consensus. Coordinating and steering these processes towards defined objectives, like the zero-growth objective, is demanding. Previous lack of goal-achievement has (partly) been explained as resulting from the complex and fragmented organisation of land-use and transport planning, embedded goal conflicts in such processes, and the lack of a power or institution that can coordinate organisations and steer towards defined objectives (Bryson, Crosby & Stone, 2015; Hanssen, Mydske & Dahle, 2013; Hull, 2005, 2008; Stead & Meijers, 2009).

Knowing this, “urban-growth agreements” (UGA) the National Government introduced as key tools and incentives to achieving the zero-growth objective (Ministry of Transport and Communications 2017). The UGAs are binding agreements between national, county and municipal authorities on how they shall develop land-use and transport systems in ways contributing to achieving the zero-growth objective in the relevant urban regions. All three levels work together, across relevant sectors, in suggesting alternative ways of developing land-use and transport systems, and in analysing whether the suggested alternatives eventually will result in zero-growth. The final decisions on the packages of measures to be implemented over a (normally) ten-year period are made through negotiations between national transport authorities and regional and municipal political representatives. Funding for projects comes partly from toll rings and partly from state, regional and municipal budgets. The national government grants 66% of the investment costs for large infrastructure projects, with the county and municipal contributions mainly covered by toll-road payment and through ordinary budgets. The UGA structure is currently open to nine larger urban areas and, by 2019, the largest four have signed: the Oslo, Bergen, Trondheim and Stavanger regions. For 2018–2029, national authorities have allocated almost seven billion EUR through the UGAs. See Tønnesen et al. (2019) or Ministry of Transport and Communications (2017) for more information about the UGAs.

Reallocation of road and street space to other uses

Reallocation of road and street space to uses other than driving and parking private cars seems like obvious interventions when aiming at zero-growth or reduction in traffic volumes. The reallocation can achieve more attractive and liveable cities and urban regions, with vibrant and accessible city centres that have efficient, safe and convenient mobility systems. These mobility systems stimulate travel by active modes, and reduce both local and global pollution from transport, as well as land take.

Reallocation of road space to other uses affects travel behaviour through several mechanisms. Focussing first on direct effects affecting the competition between modes, and assuming that people aim at reducing travel time, improving travel comfort and/or reducing direct expenses, the absolute and relative qualities of the transport systems (for car, public transport, bicycling, walking) matter for people's travel behaviour. If travel is fast, comfortable and cheap, one would expect trips to be more frequent and, on average, longer than if travel is expensive, uncomfortable and time-consuming. If conditions for using one mode of transport become better, compared to conditions for using other modes, the share of this mode will increase (Cairns et al., 2001; Downs, 1962, 2004; Goodwin, 1996; Mogridge, 1997; Noland and Lem, 2002; SACTRA, 1994). Hence, if travelling by public transport, bicycle or foot becomes relatively better (faster, cheaper, more comfortable and safer) than travelling by private car, this would influence the modal choice and contribute to reduced car shares and traffic volumes. In this perspective, the reallocation of street space in the city away from driving and parking for private cars, to instead improving conditions for cycling, walking and public transport, would be expected to improve the competiveness of sustainable modes versus the car. Reallocation of road space on main roads to public transport lanes or freight transport lanes, would alter the competitiveness between the private car and public transport.

Reallocation of road and street space also works through indirect mechanisms. Focusing on the denser urban areas and city centres, reallocated street space could give more room for public life, socialising, trees, parks, playgrounds, outdoor cafés and other things, making walking and cycling more pleasant, enjoyable and interesting, and hence more competitive versus the car (Carmona et al., 2017; Ewing and Handy, 2009; Forsyth and Krizek, 2010; Speck, 2012). This also makes walking to public stops more attractive, and therefore increases public transport competitiveness.. All this also contributes to achieving objectives like those mentioned above, for instance improved public health and more vibrant city centres. It can also make living in dense urban areas more attractive, and thus reduce traffic volumes in the city, as those living and/or working in dense inner city areas and city centres generate less traffic than those living and working elsewhere (Newman and Kenworthy, 2015; Næss et al., 2019, Wolday et al., 2019).

Taking the regional and long term dynamics between development of land use, transport systems, travel behaviour and traffic volumes into account, reallocation of road and street space to other uses can have a strong impact. It is well known and documented that increased road capacity in congested transport systems induces car-dependent land use sprawl, causing increased transport demand, higher car-shares and increased traffic volumes (Cervero, 2003; Downs, 2004; Newman and Kenworthy, 2015; Noland and Lem, 2002; Næss et al., 2019; Tennøy et al., 2019a; Wägener and Fürst, 2004). In urban areas with high potential for sprawl, these processes continue until traffic growth causes renewed congestion, with more people "stuck in traffic" than there were before (Downs, 2004), an urban structure that is harder to serve by other modes than cars and a perceived demand for road capacity expansions to ease congestion and improve accessibility (Tennøy et al., 2019a). Knowing this, one would expect that reducing road capacity, by for instance reallocating road space to other uses, would result in less sprawl and less traffic.

Suggestions for reallocating street and road space, or to not expand road capacity in congested situations, are often met by arguments that this might cause increased congestions, problems for people in their everyday lives, reduced profitability for commercial traffic, less people visiting the city centre, etc. These reactions could be a result of not considering the relevant dynamics, and of not understanding the behavioural responses to changes in the transport systems. In their well-referred article, Cairns et al. (2001:21) analysed 70 case studies of road space reallocation from eleven countries, and found that "*well-*

designed and well-implemented schemes to reallocate road space away from general traffic can help to improve conditions for pedestrians, cyclists or public transport users, without significantly increasing congestion or other related problems". In Norway, as well, there have been several examples of capacity reductions on urban roads, where information about what is about to happen has resulted in reduced traffic volumes and far less congestion and chaos than expected (Torp and Eriksen 2009), and where temporary increases in congestion and delays were reduced when people changed travel behaviour (Asplan Viak 2008).

Despite the reported experiences from cities across the world, and quite recent experiences in Oslo and elsewhere in Norway, transport authorities, commercial transport actors, political decision makers and the public seem to expect more congestions and problems with a reduction in road and street capacity, than the empirical findings in the research literature describe (Tennøy 2010, 2012). As a result, authorities may expand road capacity or refrain from reallocating road and street space to other uses, based on faulty assumptions or a lack of documented knowledge, when the documented knowledge could have helped them achieve prioritised objectives. This was the key motivation when initiating the research project BYTRANS (described below): to investigate adaptions to, as well as effects and consequences of, a number of planned changes in the transport systems in Oslo.

Previous research offered knowledge concerning how people could be expected to adapt to the changes in the transport systems. One important source was Cairns et al. (1998, 2001), describing a number of documented behavioural responses to changes in the transport systems. They found that people might change routes, change when they travel, change the transport mode, their travel frequency, what they do during the trip, and they might change their journey destination. Over a longer period, people may also move or change jobs.

Previous research has also provided explanations and evidence on how urban freight and distribution companies can adapt to increased delays in specific parts of the transport system (Allen et al. 2000, Browne et al. 2003). These can be summarised as changing scheduling, trip timing, routes, delivery frequency and size, vehicle fleets, or modes of transport. They can also negotiate contracts, reorganise routes or hire more drivers. Alternatively, they can continue operating as before. Truck drivers may have few adaption alternatives beyond starting their route earlier to reach all the planned deliveries, selecting alternative roads where possible, or working more efficiently/faster. Effects may encompass increased use of specific routes, longer travel distance (for detours), reduced punctuality, and missed or delayed deliveries (Allen et al. 2000, Browne et al. 2014, Ivanov et al. 2008, Mesa-Arango et al. 2013), causing consequences such as increased average vehicle operational cost and reduced profitability for the freight and distribution companies. Consequences for truck drivers may be increased stress, longer working days, and less convenient working hours, possibly resulting in health and safety problems (Crum and Morrow 2002, Mayhew and Quinlan 2006, Nævestad et al. 2018).

Reallocation of road and street space in Oslo: Adaptations, effects and consequences

Oslo Urban Region: A brief introduction

Oslo and the neighbouring county Akershus have stated a joint objective, in their common regional plan, of halving their CO_2 emissions by 2030 (Municipality of Oslo and County of Akershus 2015). Oslo and Akershus is also one of four urban regions having signed Urban Growth Agreements (UGAs) so far. Within this framework, zero-growth is to be obtained for the Oslo and Akershus region as a whole. Oslo was appointed as the European Environmental Capital 2019, and received the European Sustainable City Award in 2003.

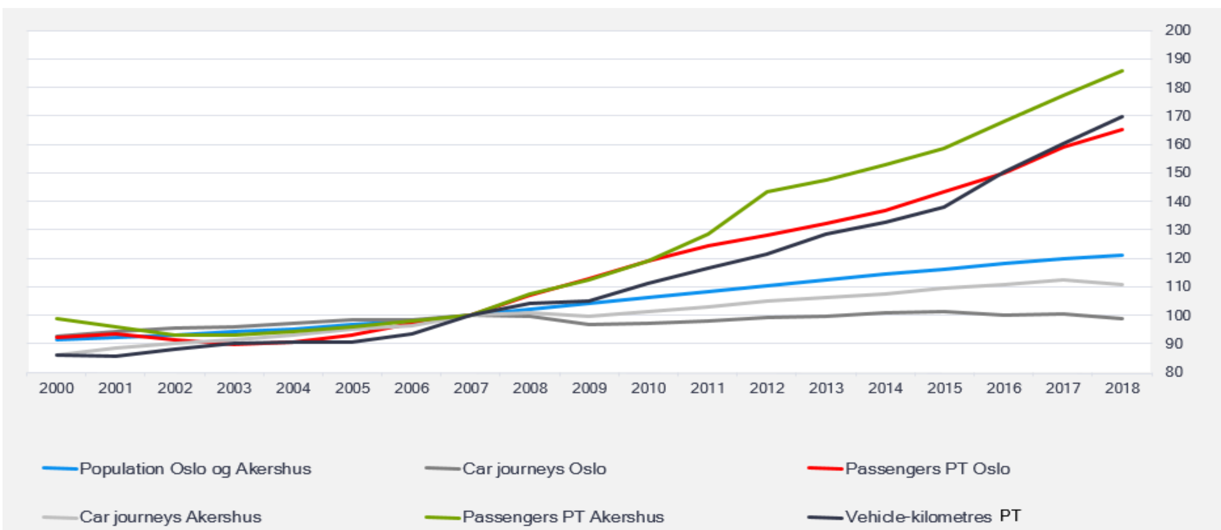
The counties of Oslo and Akershus have together about 1.3 million inhabitants (2018), of which 52% in Oslo and 48% in Akershus (Statistics Norway, 2019). The continuous urban area of Oslo (the morphological city) has about one million inhabitants, two thirds of whom live in the county of Oslo. There has been a strong population growth in the two counties, by about 20% from 2008 to 2018, and 8% from 2013 to 2018. The relative growth has been similar in the two counties. The growth has resulted in increased density in the urban region, that is a result of cultural change toward higher popularity of 'urban lifestyles' and planning policies motivated by sustainability concerns (Næss et al., 2011).

In the period 2015-2020, numerous changes have taken place in land use and transport systems in the Oslo Urban region and in the city of Oslo. The population has increased by about 30 000 in Oslo and almost 60 000 in the region as a whole, resulting in, among other things, the construction of new housing and workplaces. This construction has densified and transformed the inner and central parts of Oslo city. Also in the transport system, there has been significant changes. This concerns continuous improvement of the public transport services (for instance increased vhkm travelled for public transport – illustrated in Figure 2). In 2016, the opening of a new metro station allowed for new and better connections and a large-scale reorganisation of the metro system. Parking fees for on-street parking has been introduced in the inner city, with higher fees for visitors and lower fees for inhabitants. The city removed on-street parking in the inner city to give room for bike lanes, and give room for nine continuous bike routes through the inner city to the city centre. Ten tunnels on the main-road system have been undergoing substantial rehabilitation. The work required partial closing of the tunnels, thereby significantly reducing the road capacity. Road-tolls increased in 2017, and in 2019 an 'inner toll ring' was established to also toll those driving in the city. The City Government initiated their 'car-free city centre' project, to make the city centre (essentially the central business district) more vibrant, enjoyable and accessible by modes other than the private car. Most street parking has been removed in the city centre, pedestrian areas and pavements have been expanded, bike lanes have been built, and measures have been introduced to stop through-traffic (there was not much, as tunnels take almost all through-traffic).

These changes have probably contributed to the development illustrated in Figure 2. It shows that public transport services have improved, resulting in significantly stronger growth in the number of public transport passengers in Oslo and Akershus compared to the population growth, and a lower increase in passenger car traffic.

In their regional plan, Oslo and Akershus aim at contributing to the positive trend, and to reducing CO_2 emissions significantly. As high proportions of CO_2 emissions in the region come from road traffic, they need to reduce traffic volumes as well as continuing the shift towards electric vehicles. According to the regional plan, new land use development is mainly to be concentrated in the dense inner city, in the continuous urban area (particularly as densification around transit stops) and in five to six "regional towns" along the railway lines, with some development also in other "prioritised urban settlements". 80-90% of population growth should take place within the above-mentioned areas. To utilise transport infrastructure better through more balanced inward and outward commuting, a higher proportion of the workplaces, particularly within 'high-qualification trades', should exist in the outer parts of the region and especially in the northeast. This is assumed to reduce commuting distances (Municipality of Oslo and County of Akershus 2015). This latter strategy might probably contribute to a slightly higher car traffic growth from residential development in the upcoming decades than in 2000-2016 (Wolday et al. 2019).

Figure 2. Key figures for development in Oslo and Akershus



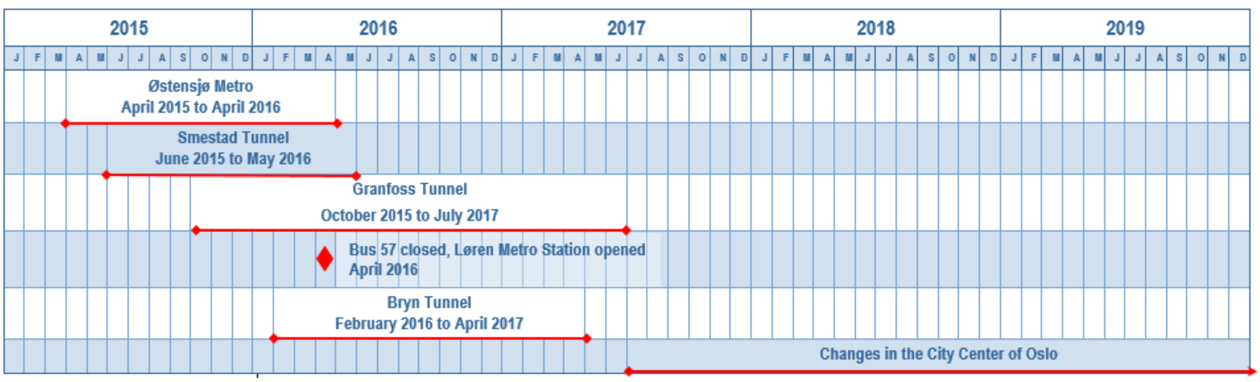
Source: Annual report 2018, Ruter (2019).

The regional plan presents guidelines rather than concrete projects for the development of the transport system, and it refers to other relevant plans, assessments and policy documents. The plan focuses on developing the transport system to connect different parts of the region, the better utilisation of transport infrastructure, and the need to meet the zero-growth objective. It describes major rail and metro infrastructure projects, which will increase capacity, frequency and coverage by rail and metro, along with intentions to reallocate road and parking space to public transport, cycling and walking, and parking restrictions. The plan mentions congestion in the road system mainly as a problem for commercial transport and suggests reduced private car-traffic as the best way to improve the situation. The plan explicitly states that "road-building your way out of congestion" is not a feasible option. Interestingly, it does not mention two large-scale urban road capacity expansion projects under planning in the Oslo region, which probably will cause increased road traffic. Instead, it states that they will build larger road projects in accordance with priorities in the so-called Oslo package 3 that is closely related to their UGA.

The BYTRANS research project

Knowing that significant changes would take place in transport systems in Oslo in the period 2015-2020, researchers from the Institute of Transport Economics saw these changes as natural experiments, offering great opportunities for investigating how different groups of transport users adapted to the changes. They also offer opportunities to investigate the effects and consequences for the transport systems, as well as the different users of the transport systems, along with the local and global environment. This could provide important and useful knowledge for authorities and others when developing more efficient and sustainable cities and urban transport systems for the future. The researchers initiated a large-scale research project, by inviting local, regional and national transport authorities, planning authorities, private transport actors and others to develop a project proposal addressed to the Norwegian Research Council, and to cooperate in and cofinance the project. The project was granted, and has been running since 2015 (and will close in June 2020). The main cases the researchers investigated were capacity reductions in two main road tunnels, the 'car-free city centre', and changes in the public transport system (the latter will not be discussed here), see timelines in Figure 3. The project was set up to both investigate the selected cases in depth, to monitor responses to other changes in the system, as well as how road-users and others experience the totality of the changes in the systems.

Figure 3. Timeline for the changes in the Oslo transport system investigated in the BYTRANS project



Source: Data from NPRA, figure from Tønnesen et al. 2019 and Tønnesen et al *(forthcoming)*The main data, methods and sources for data collections for all cases were:

- Traffic volumes from traffic registration points operated by national and municipal transport authorities
- Average traffic speed on road links, from the service reisetider.no, by the national road authorities
- Data on commuters' and city-centre users' adaptions to changes in the transport systems, and the effects and consequences they experienced, from surveys with employees in companies located within the border of the Municipality of Oslo (plus the eastern parts of the Bærum Municipality) every spring (May/June) from 2015 to 2019, and interviews with commuters recruited through the survey
- Data on truck drivers' adaptions, and the effects and consequences they experienced, from surveys and interviews with truck drivers and transport planners in freight companies in the years 2015 – 2019, all conducted by researchers from Institute of Transport Economics
- Data on taxi drivers' adaptions, and the effects and consequences they experienced, from surveys and interviews with taxi drivers in the 2015 and 2016, by researchers from Institute of Transport Economics, and analyses of data from the trip-data system of a major taxi operator
- Other data collected, but not used in this paper: Public transport passenger data, public transport speed, bicycle traffic data, information about changes in the transport systems from authorities.

Traffic data in the same predefined weeks every year from 2015 to 2019, and historical data for the same weeks back to 2014 were retrieved when available. Researchers selected weeks understood as stable with respect to the weather and the traffic situation, and weeks that were relevant when monitoring significant changes in the transport systems. The selection was also affected by data availability, as some traffic registration points were installed to monitor effects of the investigated changes in the transport system. The main reasons for analysing selected weeks, instead of all weeks, were to be able to monitor effects of the changes in the system and to control whether other major incidents in the system affected the data. In most analyses of traffic data, the focus was on rush hour traffic, when the traffic load is heaviest.

Respondents to the surveys were recruited through their employers. Using geocoded information from the Central Register of Enterprises (Statistics Norway), invitations to participate in the survey were sent to a large number of randomly selected companies located within the borders of Oslo Municipality, as well as in eastern parts of the neighbouring municipality Bærum. Those companies agreeing to participate could either send the researchers email addresses to their employees so that researchers could send questionnaires directly to them, they could forward an pre-written email to all their employees, or they could ask their employees to participate via their intranet or similar. This means that researchers cannot know whether the sample of respondents is representative of employees working in companies located in Oslo and eastern Bærum (as the characteristics of the total population is unknown), or if they are representative for those being invited to participate in the surveys (as the characteristics of those invited are unknown). Hence, researchers cannot know whether there are any systematic patterns concerning who participated and who did not. The researchers knew this when designing the study, which did not aim at statistical generalisation. We do know the location of respondents' workplaces, and the sample is representative with respect to location of workplaces within the relevant geographical area. The number of respondents were relatively high, varying from n= 4 270 (2015) to n= 6 768 (2016). The surveys had one "monitor-part", with the same questions every year and which all respondents were asked to answer, and one or more "case-parts", which the researchers asked those working in areas believed would be more affected by the investigated changes to answer. The reasons for the latter were i) that the researchers were more interested in knowing how those that were affected by the investigated changes in the transport systems adapted and what effects and consequences they experienced, rather than knowing how many in the Oslo region were affected by each change, and ii) the researchers did not want to tire out all respondents with very long questionnaires. Around 30% of the respondents agreed that they could participate in follow-up interviews, and this allowed the researchers to select interviewees with different characteristics, travel behaviour and experiences.

Recruiting truck drivers and taxi drivers to the surveys was challenging, as has also been reported in other studies recruiting professional drivers (see, e.g., Nævestad et al., 2019). The number of survey respondents remained low, varying from n=41 (2015) to n=89 (2019), despite the researchers made real efforts and cooperated with relevant actors. For the same reasons as with commuters (described above), we cannot know whether the sample is representative, and this increases the risk that any mechanisms affecting the sample will influence the results. Repeated interviews with a defined group of truck drivers provided more in-depth information about adaptions, as did interviews with transport planners working for the freight companies. Taxi drivers were interviewed in group interviews.

Capacity reduction in main road tunnels: Adaptions, effects and consequences

Ten tunnels on the urban main road system in Oslo needed to undergo substantial rehabilitation works in the period 2015 – 2020, due to EU directives (EU, 2004). For three of these tunnels, the rehabilitation works required to close two of four lanes at a time, while two-way traffic was permitted in the open tube, and the works lasted for a year or more. These are dual tunnels, carrying 30 000– 70 000 vehicles a day (AADT), and they are located on the main ring road (Ring 3) in Oslo (see Figure 4). When the rehabilitation works were finished, both tubes opened for traffic, and the tunnels regained the same capacity as before the rehabilitation works started. Ring 3 distributes traffic between different parts of the city, the region and the country. Traffic is similar in both directions, also in rush hour. Speed limits are normally 70 km/h, and were reduced to 50 km/h during the rehabilitation periods.

Figure 4. Map showing Ring 3, the relevant tunnels and the main road system in Oslo

Source: Based on Google Maps.

The authorities expected the capacity reductions in all three tunnels to cause significantly increased congestions and delays. Before the Norwegian Public Roads Administration (NPRA) started the rehabilitation work in the Smestad and the Bryn tunnel, they ran large information campaigns warning road users that the capacity reductions probably would cause heavy congestion, and encouraged users to find other ways of travelling in rush hours (see Tønnesen et al. *in review* for detailed descriptions and analyses of the information campaigns).

The BYTRANS project was set to investigate all three tunnels. The idea was to gain knowledge on how different groups of road user (commuters, truck drivers, taxi drivers) adapted to the capacity changes, and what effects and consequences they experienced. This could provide useful input to future debates concerning reallocation of road space in the main road system from private cars to other uses (for instance public transport lanes, freight transport lanes or bicycle infrastructure), and in debates concerning the need to expand road capacity in congested systems. Findings would also be useful for authorities in future situations where rehabilitation works cause the need to reduce road capacity, creating similar situations as those investigated here. The capacity reduction in the first tunnel undergoing rehabilitation works, the Smestad tunnel (AADT 50 000), resulted in almost no measurable effects. Hence, the researchers decided to *not* investigate the next tunnel to be rehabilitated (the Granfoss tunnel, with AADT 30 000), and instead focus on the Bryn tunnel with AADT 70 000.

Based on existing literature (described above), the research was designed to answer the following research questions:

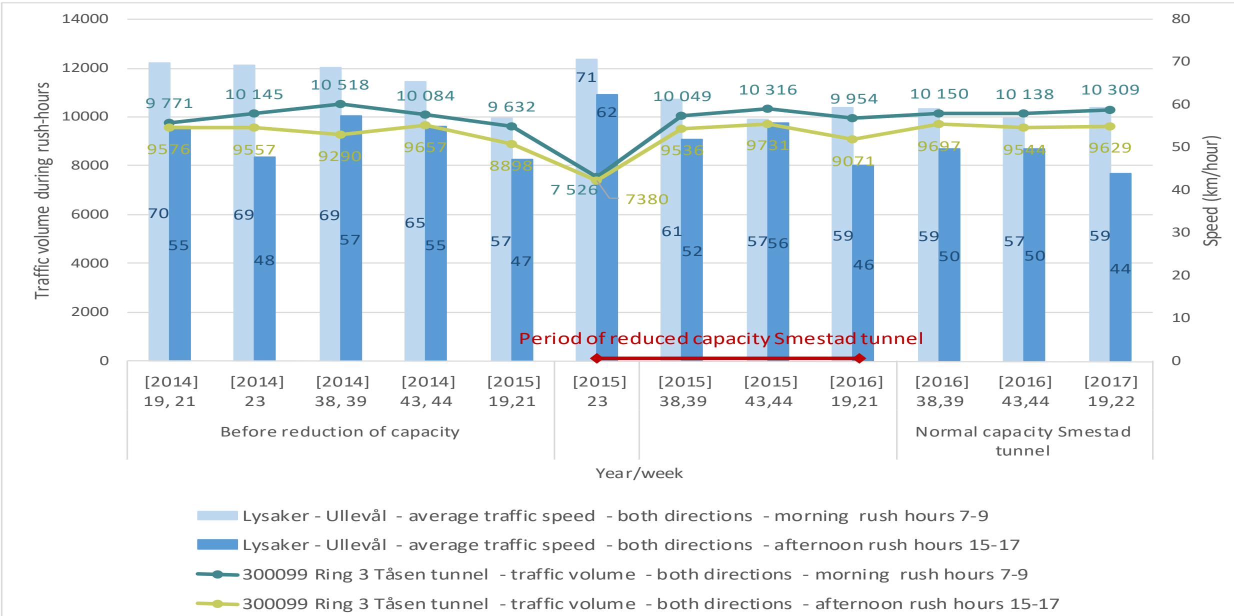
- How did the capacity reduction in the tunnels affect traffic volumes and average speeds in and close to the tunnels?
- Which effects and consequences were experienced in other parts of the road transport system?
- How did commuters, truck drivers and taxi drivers adapt to the capacity changes?
- What effects and consequences did commuters and truck drivers experience?
- Did the information about the changes reach the road-users, and did they have any effects?

Adaptions could be to change routes, modes of transport, trip timing, trip frequency, travel behaviour, etc. Effects could be changes in congestion, delays, time-usage, traffic situation reliability, etc. Wider consequences for commuters could occur if they changed routines and responsibilities within the household, and if their satisfaction with their commute changed. For freight transport and taxi transport, this could concern variability in delivery time, the need for detours, and quality of the workdays for the drivers.

Results: The Smestad Tunnel

The main result from investigating adaptions to, and effects and consequence of, halving the capacity in the Smestad tunnel, was that not much happened (see Tennøy et al., 2015 and 2016 for fuller descriptions of the case-study design and the results). Two of four lanes in the tunnel were closed from 1 June 2015 to 22 May 2016. A successful information campaign resulted in significantly reduced traffic on this part of Ring 3 the first day after the capacity reduction (down 37% and 3 500 vehicles in the two-hours morning rush from 07:00 to 9:00 when summarizing both directions, and down 33% and 3 200 vehicles in the afternoon rush hours from 15:00 to 17:00). Many of those normally driving through the Smestad tunnel and this part of Ring 3 found other alternatives these days. There are no indications in our data that they chose other routes on the road network, and we assume that commuters either chose other modes or worked from home. As a result, the traffic was free-flowing on the affected link (and in the road transport system in Oslo in general the day the capacity reduction was implemented), and the expected congestion did not occur, see Figure 5.

Figure 5. Average traffic volumes and traffic speed, weekdays in selected two-week periods, in morning rush hours (7:00-9:00) and afternoon rush hours (15:00–17:00)



Source: Data from NPRA, figure from Tønnesen et al. 2019 and Tønnesen et al. *(forthcoming)*.

The press geared up to cover congestion and chaos, but ended up reporting that traffic was smoother than ever. Already the second day after the capacity reduction was implemented, traffic started to increase. Three months later, traffic volumes were back at normal levels. Only small increases in delays were found, despite the fact that the road capacity had halved. In accordance with this, there were no indications in the data that traffic was redistributed to other roads, or that road-users had made any adaptions to the situation. Commuters reported no, or few, effects and consequences, as did truck drivers and taxi drivers. This is likely because the Smestad tunnel had enough capacity, with one, instead of two, lanes in each direction to carry the traffic load it had before the capacity reduction (about 1 400 vehicles per hour, one direction). The traffic is about equal in both directions, also in rush hour, and much of the traffic is dispersed throughout the day. Hence, peak traffic volumes are probably lower than in many other roads with similar AADTs. Interestingly, these findings caused debate among professionals working in the Oslo area, and some doubted that the results could be correct. This concerned, among other things, the maximum capacity per lane per hour.

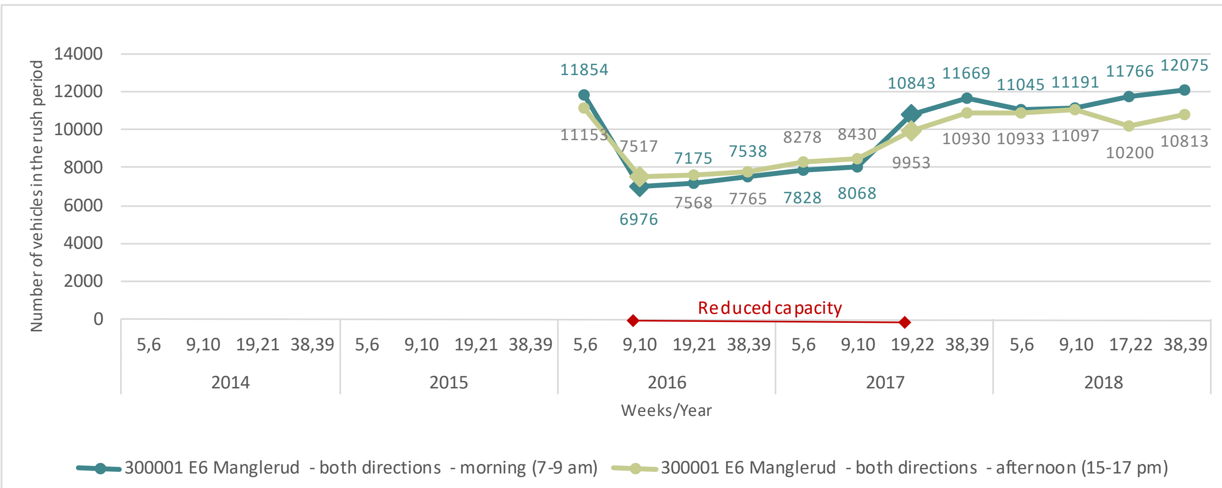
Results: The Bryn tunnel

The Bryn tunnel is located on the part of Ring 3 with the heaviest traffic, and it carries about AADT 70 000. Traffic volumes are almost equal in both directions, including during rush hour. The average traffic per weekday in calendar weeks five and six of 2016 was about 82 000 vehicles a day, and of these, about 9 900 vehicles were longer than 5.6m (understood as mainly freight and distribution transport). The capacity in the tunnel was reduced from four to two lanes in the period of 20 February 2016 to 29 April 2017. The capacity reduction in the Bryn tunnel was expected to cause more congestion and delays than in the other tunnels, as it had the highest traffic volumes, and the capacity would be reduced for 14 continuous months.

Changes in traffic volumes and speeds

The total traffic volumes through the tunnel went down during the capacity reduction, by 26-34% in rush hour and by 23% per day, returning to about the same levels as before when the tunnel regained normal capacity. Figure 5 illustrated traffic in morning and afternoon rush hours (total traffic for two rush hours, and in both directions, average for weekdays in two-week periods). The researchers did not find similar traffic reductions at the reference point, E18 Ramstadsletta.

Figure 5. Average traffic volumes, E6 Manglerud, during morning rush hour (7:00–9:00) and afternoon rush hour (15:00–17:00), summing both directions for selected weeks in 2016, 2017 and 2018.

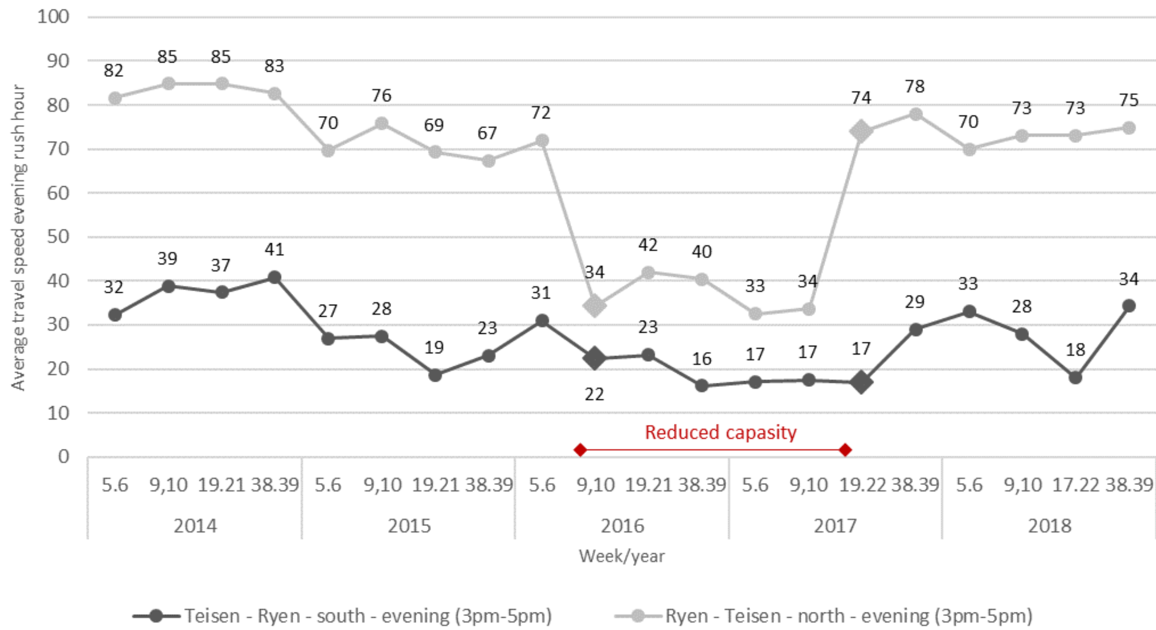


Source: Facsimile from Tennøy et al 2019c, data from the Norwegian Public Roads Administration [NPRA].

Despite the substantial traffic reduction, the average speed on the part of Ring 3 including the Bryn tunnel was significantly reduced in both the morning and afternoon rush hours (see Figure 6). In the before and after situation, average measured speeds were close to, or above, the speed limit (70 km/h), except from southbound traffic ("out of the city") in the afternoon rush hour where average speed was about 30 km/h. During the capacity reduction, speed limits were reduced to 50 km/h, and the average measured speeds to 30–40 km/h. Again, the southbound traffic in afternoon rush hour was the exception, with average speed reduced to about 20 km/h. Comparisons of weeks five and six in 2016 and 2017 revealed extra time used on the 3.3 km long Teisen-Ryen road link in 2017 varying from 2.5 minutes (morning, southbound) to 5.1 minutes (afternoon, southbound). When also including the road links to the south and to the north of the Teisen-Ryen road link, extra time used on the 13km stretch between Klemetsrud and Grefsen varied from 2.5 minutes (morning, southbound) to 12 minutes (afternoon, southbound).

Average speeds in the hours adjacent to rush hours were also analysed. In the normal situation, traffic was almost free-flowing, at speeds close to, and higher than, speed limits (70 km/h). In the period when the capacity and the speed limit were reduced (to 50 km/h), average measured speeds were reduced to around 30-50 km/h in different hours (adjacent to rush hours) and directions. This was most evident in the northbound direction ("into the city") between 9:00 and 10:00 in the morning, when average speeds (over two-week periods) were down to 30 km/h.

Figure 6. Average speeds of the Teisen–Ryen route on the weekday morning rush hour (7:00–9:00) to the left and on afternoon rush hour (15:00 – 17:00), on weekdays in selected two-week periods.



Source: Facsimile from Tennøy et al. 2019c, data from the Norwegian Public Roads Administration (NPRA).

Commuters' adaptions to the capacity reduction

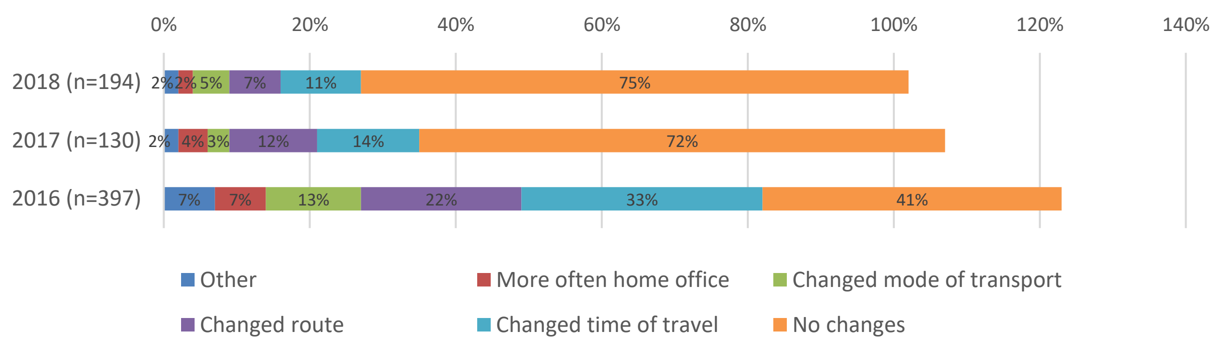
In the survey with employees working in businesses in the Bryn area (June 2016), 40% of the respondents answered that their commutes had been affected, positively or negatively, by the capacity reduction in the Bryn tunnel. Of these, 41% had not made any changes to their commutes to adapt to the situation. 33% answered they had changed the starting time of their commute, 22% that they had changed routes, 13% that they had changed mode of transport, 7% that they had home-office more frequent, and 7% other changes (see Figure 7). Among car-drivers, fewer reported "no changes" (34%). 43% of them said they had changed when they travelled, and 28% that they had changed routes. As Figure 7 shows, a large majority of respondents reported in 2017 and 2018 that they had not made any changes in their commute to adapt to the capacity expansion back to four lanes in the Bryn tunnel.

The BYTRANS project was designed to measure road users' adaptions to the capacity reductions also in other ways than asking people directly through surveys. Using traffic data from the registration point closest to the Bryn tunnel, E6 Manglerud, to analyse if traffic increased in the hours before and after rush-hours, the researchers found that traffic was reduced in these hours in the period with capacity reduction. This finding is not in accordance with what respondents answered in surveys. It is likely because they adjusted their trip timing somewhat, to compensate for the extra variability and the extra time used, and not that they made more substantial changes in trip timing.

The researchers also analysed changes in traffic volumes on alternative routes, to see if there was any measurable evidence of rerouting of traffic. They found a 12-37% increase in traffic volumes on the most relevant alternative route in the main road system (the Svartdal tunnel), when comparing traffic volumes in weeks 38 and 39 in 2015 and 2016, indicating that this was used as an alternative route. The researchers found small increases on a route taking traffic around Oslo and on relevant municipal roads. They also found increased rush hour delays on a north-south main road route (E6 Karihaugen-Helsfyr) crossing

Ring 3, caused by the increased congestion around the Bryn tunnel. Apart from this, it seems that the effects of the Bryn tunnel capacity reduction were mainly limited to the road network in close proximity to the tunnel.

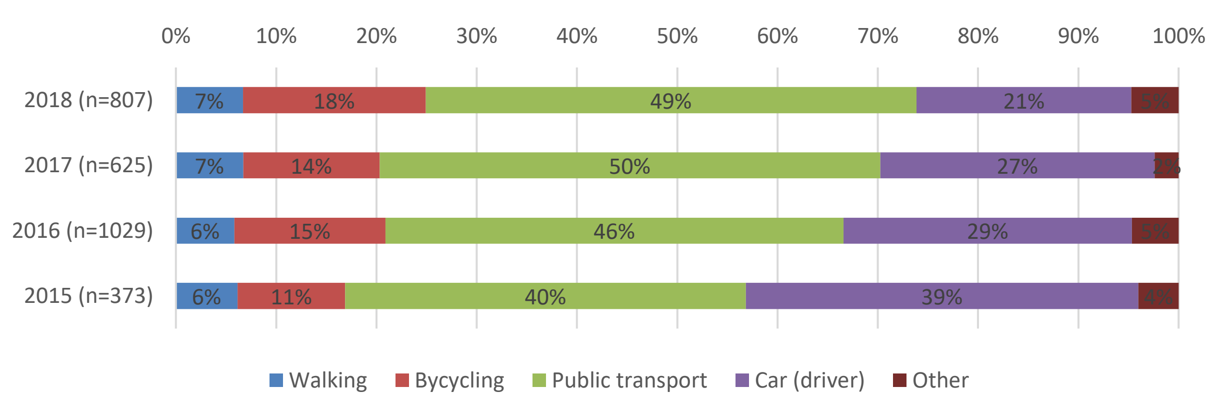
Figure 7. What changes respondents had done in their commutes, to adapt to capacity changes in the Bryn tunnel. Multiple answers allowed. Question asked only to those answering that their commutes had been affected by the capacity changes.



Source: Facsimile from Tennøy et al 2019c.

In the surveys conducted in 2015, 2016, 2017 and 2018, researchers asked what mode of transport respondents had used for the longest part of the journey last time they travelled to work. Researchers met them where they normally meet. Answers to this question revealed a substantial change in modal split amongst respondents working in businesses located in the Bryn area. We found a substantial decrease, from 39% in 2015 to 29% in 2016 of respondents answering that they had been driving (see Figure 8). The decrease continued to 27% of car-drivers in 2017 and 21% in 2018. The share of respondents answering that they had travelled by public transport and bicycle increased. Important to mention her is that a metro line was closed for rehabilitation when the 2015 survey was done, and had reopened before the 2016 survey. One of the large businesses participating in the surveys introduced a parking charge in the same period. In comparison to these results, only 13% answered in the survey that they had changed mode of transport as an adaptation to the capacity reduction in the Bryn tunnel.

Figure 8. "What mode of transport did you use for the longest part of the trip last time you travelled to work and meetings?"



Source: Facsimile from Tennøy et al 2019c.

Researchers also asked how often respondents had worked from home remotely the previous week. In 2015, 89% answered “never”. This decreased to 82% in 2016 and to 76% in, and increased back to 81% in 2018. Interviewees told that their employers had been less strict about the use of home-office in the period with capacity reduction, to ease the negative impacts, and the interviewees appreciated this. “This increase in working from home matches the participants’ responses when asked how they would adapt to the capacity reduction of the tunnel.”

Truck drivers’ and taxi drivers’ adaptions

Analyses of traffic data showed that only a minority of drivers of long vehicles (longer than 5.6m, representing freight and distribution vehicles here, but also including other long vehicles) adapted to the capacity reduction by avoiding the Bryn tunnel in morning rush hour and during the day (see also Caspersen et al. *in review* for more detailed information). The number of long vehicles decreased by 4% (386 vehicles) per day compared to weeks five and six in 2016 and 2017 in the E6 Manglerud registration point and by 13% (1 523 vehicles) in the Rv 150 Hovin registration point. This was substantially less reductions than for the total number of vehicles (all lengths), which decreased by 23% and 20%, respectively. During morning rush hour, the number of long vehicles was stable at E6 Manglerud and down 14% (216 vehicles) at Rv 150 Hovin, while the total traffic volumes reduced by 34% and 23%, respectively. This indicates that only a minority of drivers of long vehicles who normally drove through the Bryn tunnel adapted by avoiding the tunnel, and that they did so to a lesser degree than other drivers did.

An increased number of long vehicles on the most logical alternative route, the Svartdal tunnel on the main road system, indicated that some drivers chose this as an alternative route. The number of long vehicles increased by 41% (838 vehicles) per day and 29% (70 vehicles) in morning rush hour (compared weeks five and six in 2016 and 2017). In comparison, the total traffic in the Svartdal tunnel increased relatively less, by 8% per day and 0% in morning rush hour (these figures differ from those reported above, where total traffic volumes in weeks 38 and 39 in 2015 and 2016 were compared, and it was found a 12-37% increase in total traffic in the Svartdal tunnel). The data also showed that drivers of long vehicles did not use the more local roads as alternative routes, as the number of long vehicles on those routes were stable or reduced. Traffic through the E18 Ramstadsletta reference point was relatively stable. After the Bryn tunnel regained full capacity, the number of vehicles in the registration point close to the tunnel increased to somewhat lower levels than in the before situation, while the traffic was reduced toward 2016 levels in the Svartdal tunnel.

Interviews with 19 truck drivers, including ten drivers who did make various adaptations and nine drivers who did not, gave more information about how they adapted. This concerned different ways of avoiding the Bryn tunnel, especially in rush hours, by using alternative roads, reorganising delivery routes, and starting earlier or later to avoid congestion and/or compensate for extra time spent. The interviews with truck drivers and transport planners were consistent in terms of whether the companies made adaptations. In both groups, some said they did and others said they did not. Adaptations included rerouting, changing departure times, and guiding truck drivers out of the most congested areas at the most congested times. Some transport planners had adaptions planned but found them unnecessary to implement. Truck drivers and transport planners alike claimed limited flexibility, due to strict customer contracts. This is in line with results from the analyses of the traffic data. After the rehabilitation work finished in 2017, truck drivers said they had mainly returned to their old routines.

Taxi drivers said, in group interviews in 2016, that they had not seen any need to adapt. They could use the public transport lanes, and were not much delayed by the capacity reduction.

Effects of the capacity reduction

The effects of the capacity reduction in the Bryn tunnel were reduced travel speeds through the tunnel, through the adjacent road links and on the north-south main road route (E6 Karihaugen-Helsfyr) crossing Ring 3, as well as increased variability in the traffic situation. As said, it seems that the effects of the capacity reduction were mainly limited to the road network in close proximity to the Bryn tunnel. Surveys and interviews of road users also revealed effects related to walking, bicycling and public transport.

In 2016, those who answered in surveys that their commute had been affected by the capacity reduction in the Bryn tunnel, were asked which changes they had experienced. Concerning negative effects, more congestion was the most frequently selected answer (58%), followed by increased travel time (57%), reduced punctuality (27%), more car traffic where they walk or bicycle (21%), increased travel time by public transport (15%) and more crowding on public transport (12%). These results were in accordance with findings in the interviews. Few respondents reported positive effects. Half of those who drove or were passengers in a car last time they went to work indicated that their commute took longer, on average nine minutes. Of those who used public transport the last time they went to work, fewer (13%) experienced changes in commuting time. When asked the same question in 2017 and 2018, after the tunnel had regained full capacity, most respondents had experienced positive changes in their commutes. Most the respondents reported reduced congestion and travel time, as well as improved punctuality.

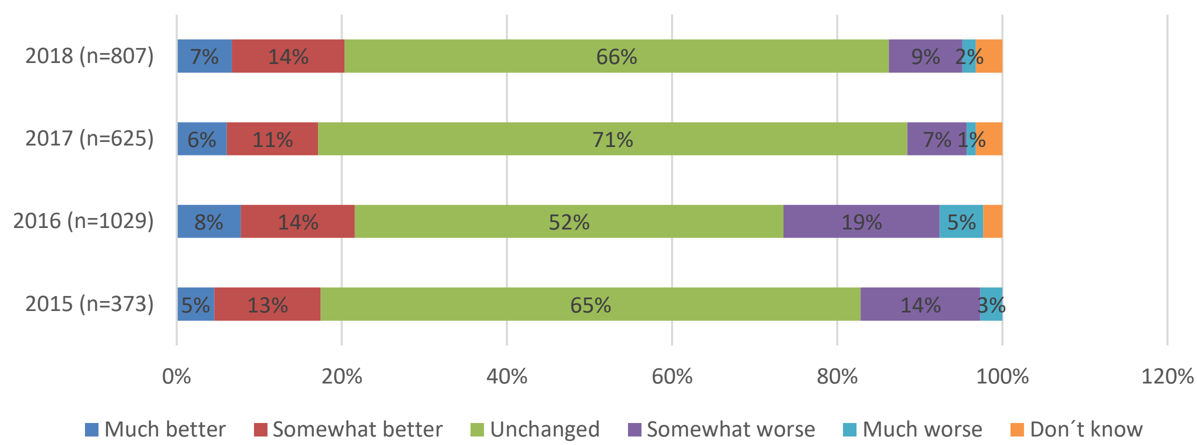
The truck driver surveys showed that the most common negative effects of the capacity reduction were increased congestion (19%), more time used on the route (16%), and more detours (14%). In the interviews, the truck drivers explained that the traffic situation had become more unpredictable. The drivers were asked about additional time spent on the route, caused by the rehabilitation work. On average, the drivers reported a delay of 10–20 minutes during rush hour. Transport planners (working in freight companies) confirmed that time spent on a route had increased and predictability decreased, as did analyses of traffic data. Some drivers and transport planners expressed that the effects were less severe than expected; they saw other issues as more problematic than the congestion related to the Bryn tunnel.

Consequences of the capacity reduction for commuters

When investigating consequences for commuters, researchers focused on changes in their satisfaction with their commutes, and whether they had felt the need to reorganise tasks or routines within the household. In the annual surveys of employees in businesses in the Bryn area, all respondents were asked how satisfied they were with their work trips (before the questions about the Bryn tunnel were introduced). Results showed that the respondents overall were quite satisfied, with the proportions of respondents who answered “satisfied” or “very satisfied” varying from 72% (2016) to 78% (2017). The share that responded “very satisfied” increased steadily over the years, from 26% in 2015 to 37% in 2018. The proportions who answered “dissatisfied” or “very dissatisfied” remained low, varying from 7% (2017) to 13% (2015 and 2016).

We also asked if respondents felt that their commute had become better or worse compared to the situation one year ago, see results in Figure 9. The share that responded “somewhat worse” or “much worse” were higher in 2016 (24% in total) than in other years (varying from 8-17%). Interestingly, the proportion that responded “somewhat better” and “much better” was also higher in 2016 (22% in total) than in the other years (varying from 17-21%). This is likely related to the reopening of a relevant metro line that had been closed for rehabilitation, and had come back in operation in April 2016. The change to this metro line is one of the cases in the BYTRANS project, but not included in this paper.

Figure 9. "Do you find your commute to be better or worse compared to the situation one year ago?"



Source: Facsimile from Tennøy et al 2019c.

Of the respondents, 12% employed in businesses in the Bryn area report that the capacity reduction and/or their adaptation to the situation had led to changes in responsibilities, routines or other changes in the household. While, 5% answered that it had resulted in changes in responsibility/routines to bringing children to and from kindergarten, school, etc.

Consequences for truck drivers and taxi drivers

The surveys asked all truck drivers whether they had experienced a worsening or an improvement in the traffic situation in the Oslo area compared with the same time last year. The share of drivers who experienced a worsening of the traffic situation peaked in 2016, with 67% experiencing a worsening of the situation, due to the works in the Bryn tunnel. The 2016 and 2017 surveys asked truck drivers who drove through the Bryn tunnel once a week or more if they had experienced a change in their workday due to the rehabilitation work in the tunnel. During the rehabilitation work (2016), most (27 out of 32 drivers) found that this had contributed to a worsening of their workday. After the rehabilitation work finished (2 017), most felt that this had contributed to an improvement (27 out of 39 drivers).

Drivers who responded that they experienced a change in their workday received follow-up questions about what changes they experienced, and they could select multiple alternatives. Only one driver reported experiencing no negative changes in 2016, and almost all (21 out of 27) reported experiencing no positive changes. The most commonly reported negative consequences were more stress and frustration (15%) and less predictable workdays (10%). Whereas, the respondents were less concerned by the more inconvenient work hours, the use of more vehicles, and the increase in problems complying with mandatory rest periods. In interviews, longer workdays were also an issue. The drivers explained that this was mainly due to the more unpredictable traffic situation and the need to depart earlier. Some also said that the congested traffic led to more risk-taking behaviour among private drivers, causing traffic safety issues. Most of the freight company transport planners reported that that reduced flexibility and efficiency resulted in increased costs and reduced profits. None reported, however, acquiring more vehicles or truck drivers because of the change in the traffic situation, despite drivers spending more time on deliveries and routes. Several claimed that the situation for delivery zones in the city centre was a bigger problem than delays on the main roads, including the worsened situation caused by the rehabilitation works in the Bryn tunnel. In 2017, after the tunnel had regained full capacity, the picture changed. Only two of 28 drivers did not report any positive changes, and 24 out of 28 drivers did not report any negative changes. The most common positive change was related to less time spent on the route (33%), followed by less congestion (21%), and less detours, easier compliance with timeframes, and less stress and frustration (all 13%).

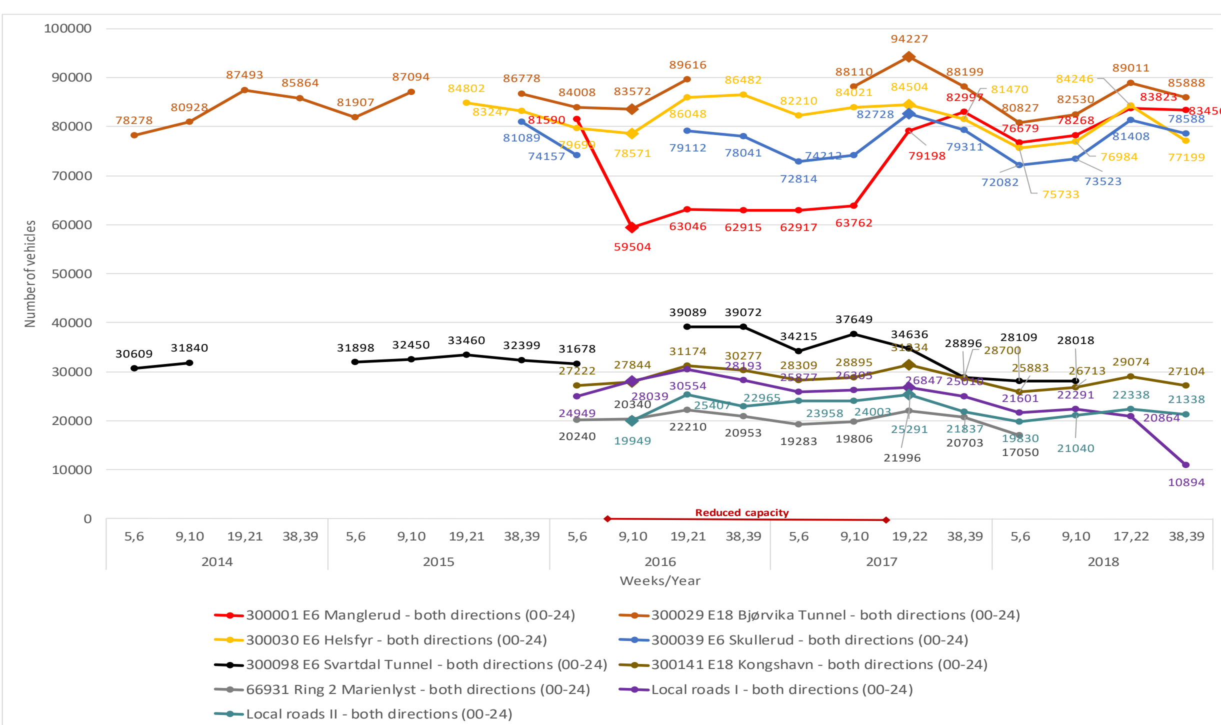
The capacity reduction in the Bryn tunnel reduced driving speeds and increased tour lengths for taxi traffic only marginally. Drivers did not report that they had made significant changes to adapt to the situation in interviews. The largest taxi centre had not made any adjustments.

Consequences for the transport system and the environment

Concerning the overall consequences for the transport systems, and based on what has been discussed above, it seems that the effects of the capacity reduction were mainly limited to the Bryn tunnel, adjacent links, and a main road crossing Ring 3. Here, delays increased significantly. When summing extra delays on the 3.3 km road link that the Bryn tunnel is a part of, extra delays were up to 5.1 minutes. When also including two adjacent links, extra time used on this 13 km stretch were up to 12 minutes (average, over two-week periods, probably meaning longer delays on some days). Roadworks on local roads in the area around Bryn, together with a small increase in traffic volumes on these roads, did (according to interviews and open answers in the survey) result in increased congestion on these roads and disadvantages for pedestrians and cyclists. Those cycling express that they were “forced” onto the pavement, which is a disadvantage for both pedestrians and cyclists. We aimed at measuring effects and consequences for public transport and cycling systems, but due to low data quality, we were unable to do so.

The NPRA measured changes in local pollution in relevant areas before and during the capacity reduction. The analyses concluded that pollution was lower in the period with capacity reduction as compared to the normal situation, probably due to lower traffic volumes and speeds (Tennøy et al., 2019c). Meteorology might have influenced on the results.

Figure 10. Traffic volumes per day, at different traffic registration points, summing both directions



Source: Facsimile from Tennøy et al. (2019c).

As previous research has found that capacity reductions might result in “disappearing traffic” (Cairns et al. 2001), the researchers analysed if that was also the case here. The researchers summarised traffic volumes from different traffic registration points, on routes understood as alternatives to each other. Getting this right is not an easy task. Some might question if a certain amount of traffic is counted twice or missing. Traffic volume in the selected registration points in weeks five and six in 2016 (before capacity reduction) was compared with traffic volumes the same weeks in 2017 (during capacity reduction), see Figure 10. The results showed that total traffic in these registration points went down by 2 800 vehicles (4.2%) in the two morning rush hours (7:00 – 9:00), by 1 900 vehicles (2.9%) in afternoon rush hours (15.00 – 17.00), and 12 300 vehicles (2.2%) per day. If these results are correct, it probably also means that the capacity reduction resulted in reduced GHG emissions.

Oslo city centre: Reallocation of streets space to other uses

The City Council Declaration from 2015 set goals for Oslo that pedestrians, cyclists and public transport users would be given priority over private car transport and that the development of a car-free city centre would be a means of achieving a more vibrant, enjoyable city centre. This has been followed by the implementation of a number of specific measures in the city centre between 2017 and 2019. On-street parking spaces (approx. 760 spaces) have been removed and a new driving pattern have been introduced to prevent through-traffic. These measures reduced accessibility by car both within, and to, the city centre. Areas freed from car use have been reallocated to other purposes, such as pavement extensions, new pedestrianised streets, more benches, bicycle lanes, bicycle parking, parking for the disabled and for deliveries. These measures improve accessibility for walking and cycling. As streets are upgraded to ensure better conditions for public transport, bicycling and walking, the construction works reduce accessibility to, and use of, city centre streets and plazas. Additional measures are in the planning stage, and a new zoning plan for the streets and plazas in the city centre sets guidelines for further development.

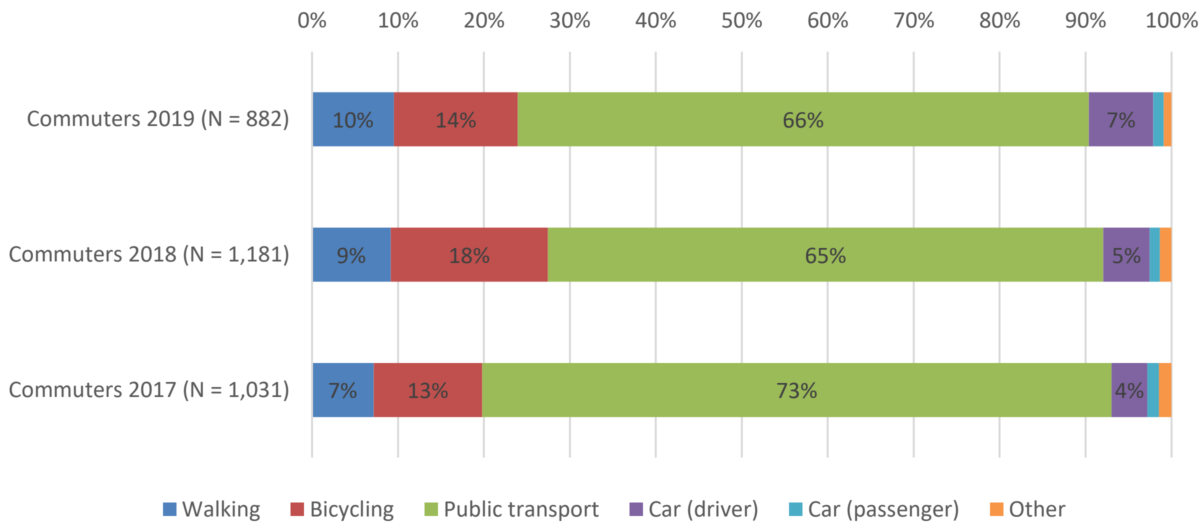
Researchers examined how commuters to workplaces located in the city centre and city centre users adapted to the changes in accessibility, and which effects and consequences these groups, as well as freight and distribution drivers, have experienced. Key methods were surveys and interviews; see the section on methodology in the BYTRANS-project above. Two sets of survey-data were analysed. When presenting findings concerning commuters to the city centre, we refer to answers from respondents working for businesses located in the city centre. When discussing city-centre users, we refer to answers from all respondents in the surveys.

Key findings are that measures implemented in the city centre have had the intended effects, although only small changes were found. There were no significant changes in travel behaviour among commuters and city centre users. The reported experiences of walking and cycling in the city centre improved from 2017 to 2019. There was a decrease in positive anticipation of how the changes will affect the use of the city centre, maybe due to high expectations for the announced changes and that these have not yet been fulfilled. Truck drivers feel the changes have worsened their situation, despite the fact that more parking spaces are now reserved for deliveries.

Commuters’ experiences

As accessibility by car to the city centre reduced, and accessibility by other means of travel improved, one could expect shifts in travel behaviour towards less car use and more use of other modes of transport on commutes. There were, however, no significant changes in travel behaviour on work trips. Car shares were already low (4% in 2017), and they actually increased (to 7%) in 2019 (see Figure 11).

Figure 11. Modal shares on work trips to the city centre in 2017, 2018 and 2019.



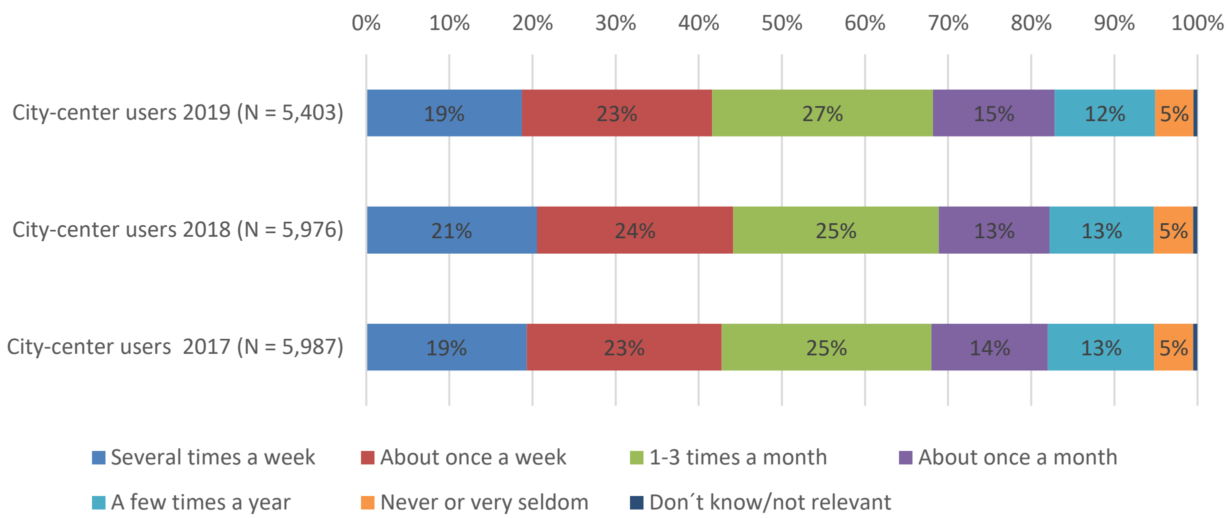
Source: Facsimile from Hagen et al. (forthcoming).

Commuters working in businesses located in the city centre are in general satisfied with their commutes, and 75% answered that they were satisfied or very satisfied both in 2017 and in 2019. Those walking and biking are the most satisfied. More detailed analyses revealed that those biking and those driving to work became more satisfied with their work trip when comparing answers from 2017 and 2019. Among cyclists, the share answering "satisfied" or "very satisfied" increased from 83% in 2017 to 89% in 2019. Among car drivers, the figures were 65% in 2017 and 76% in 2019. The latter might be surprising, as most on-street parking spaces in the city centre has been removed, and restrictions on parking in the inner city have been introduced. One explanation might be that those driving to work park in garages, and not on-street. It also seems that some employers took actions to ensure parking for their employees. Survey results showed a significant increase in the proportion of commuters to the city centre who replied that it usually is easy to find parking at, or near, their workplace from 2017 (22%) to 2019 (40%). The proportion of commuters who answered they had the opportunity to park for free at parking spaces offered by their employers increased from 19% in 2017 to 36% in 2019. This could also explain the increase in car-usage on commutes to the city centre.

City centre users' experiences

When asking how respondents travelled the last time they visited the city centre, except trips related to work, researchers found no significant changes with respect to transport mode from 2017 to 2019. Most respondents (66-69%) answered that they travelled by public transport, and fewer travelled by car (reduced from 9% in 2017 to 7% in 2019), by foot (11% all years) and by bicycle (varying from 7% in 2017 to 11% in 2018). Respondents find it easy to travel to the city centre. The proportion who answered that this is "very easy" or "easy" is stable at around 94%, and very few (2-3%) answer that it is "difficult" or "very difficult". However, more people answer that it is "very easy" to get to the city centre in 2019 (61%) compared to the previous years (55% and 56%). This may indicate that accessibility to the city centre is perceived as somewhat improved. Respondents also visit Oslo city centre often, see Figure 12. More than 40% say they visit the city centre once a week or more, and more than 80% that they visit once a month or more. There are only small variations when comparing answers from 2017, 2018 and 2019. When comparing the answers to how often they visit in the city centre and how they travelled the last time they visited, we found that those who walked and biked visited the centre most often.

Figure 12. Frequency at which survey respondents visited the city centre for non-work-related reasons".



Source: Facsimile from Hagen et al. (forthcoming).

When asked how much they enjoy being in the city centre at this time of the year (May and June), more than 80% answer "very much" or "much". The proportion of respondents answering this is quite stable, but the proportion answering "very much" increased from 27% in 2017 to 29% in 2019. When asked what they appreciate the most in the city centre, the offer of restaurants and pubs, and of culture and entertainment, are ranked the highest (59% and 47% in 2019), followed by "urban atmosphere and street life" (45%) and "access to the fjord" (42%). "Plazas and parks" are ranked number five (32%), "shops and retail" number six (31%) and "pedestrianised zones and car-free areas" number seven (29% in 2019, up from 23% in 2017). City centre users listed "street vendors, begging and drug addicts" and "too much car traffic, parked cars, buses, goods delivery etc."' most often among things they do not appreciate in the city centre (open answers, not pre-defined). Other factors that respondents specified as not appreciating include construction work and conflicts with other road users. In 2019, some respondents also mentioned electric scooters (these were first introduced in the spring of 2019). We asked how much money respondents had spent the last time they visited the city centre. Results showed an increase from 2017 to 2019. Those driving spent more money per visit, while those walking and bicycling visited more often.

Changing experiences of travelling in the city centre

Street space has been reallocated from parking and driving to other uses, and the survey results revealed that respondents appreciated this change. The proportion fully agreeing or agreeing that there is too much traffic in the city centre decreased from 57% in 2017 to 47% in 2019. For the statement "parked cars take up too much space", the figures were 50% in 2017 and 29% in 2019. More than 80% agreed or totally agreed with the statement "I enjoy walking in the city centre" in all years. We found a positive development from 2017 to 2019 when it comes to how the city centre is designed for pedestrians. In 2017, 65% agreed or fully agreed to the statement "here is sufficient space for pedestrians on sidewalks and in pedestrian streets", while 70% said the same in 2019. In 2017, 58% agreed or fully agreed that "the pedestrian areas are good for walking", while 64% said the same in 2019. While 38% in 2017 agreed or fully agreed to the statement "I feel that pedestrians have the highest priority in the city centre", 47% did so in 2019.

There were also statements concerning biking in the city centre. These statements showed small positive tendencies that indicate improved conditions for cycling. In contrast to walking, few respondents agree that biking in and through the city centre is sufficiently facilitated. For instance, only 11% agreed or fully agreed in 2017 that "there are good and continuous bicycling routes through the city centre", while 15% said so in 2019.

City centre users who travelled by car the last time they visited the city centre were asked about parking. As expected, we found an increased proportion of car users parking in parking garages and a decreasing proportion parking on the streets. The reported time spent finding a place to park increased from approximately five minutes in 2017 to seven minutes in 2018 and 2019. Still, the majority of respondents in 2019, 63%, only spent between zero and five minutes finding parking (74% in 2017). We conclude that it has become somewhat more difficult for city centre users to find parking. City centre users were also asked how they experience driving in the city centre. Unsurprisingly, respondents stated that it has become more difficult to drive in the centre in 2019 than before the changes in driving pattern were introduced. In 2018, 32% agreed or fully agreed that "it is easy to drive a car in the city centre", while in 2019, 22% said the same.

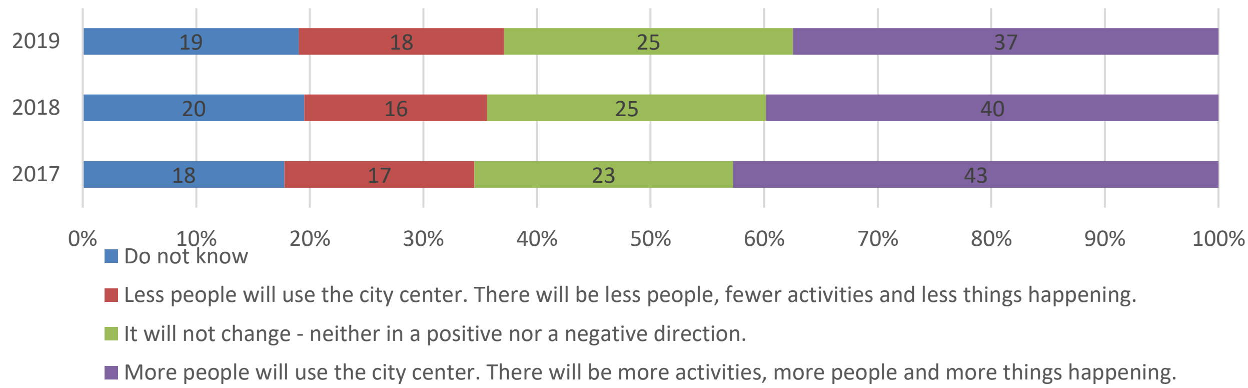
These results indicate that the experience of walking and bicycling in the centre has improved, while the experience of driving in the city centre has worsened. Even though significant shifts from cars to other modes are evident, both to and within the city centre, , these changes in perceptions of travelling in the city centre might also in the longer run affect travel behaviour.

Consequences for the city centre

It seems that respondents had high expectations concerning the changes in the city centre that has not been fully met. When the last survey was made, construction works were still going on all over the city, both due to the aforementioned, and other, changes. Respondents do believe the changes will result in more urban life and more people using the city centre, but the expectations have been reduced over the three years of surveys. We found that the proportion who believe that "more people will use Oslo city centre. There will be more activities and people, and more action and vibrancy" was gradually reduced, from 43% in 2017 to 37% per cent in 2019, while the proportion agreeing that "fewer people will use Oslo city centre. There will be less activities and people, and less action and vibrancy" was stable (17% in 2017 and 18% in 2019), see Figure 13.

In 2017, 22% of the respondents believed that they would use the city centre more often, due to the announced changes, while 12% said they would use the centre less often. In 2019, 16% said they would visit more often and 16% less often. When asked, in 2019, how the changes in the city centre had affected their use of the centre so far, more than twice as many (18%) responded that they use the centre less often than before than those who said they use the centre more often (7%). These results are not in accordance with findings described above, that there has been no significant change in how often respondents visit the city centre.

Figure 13. Respondents' expectations for the future of the city centre

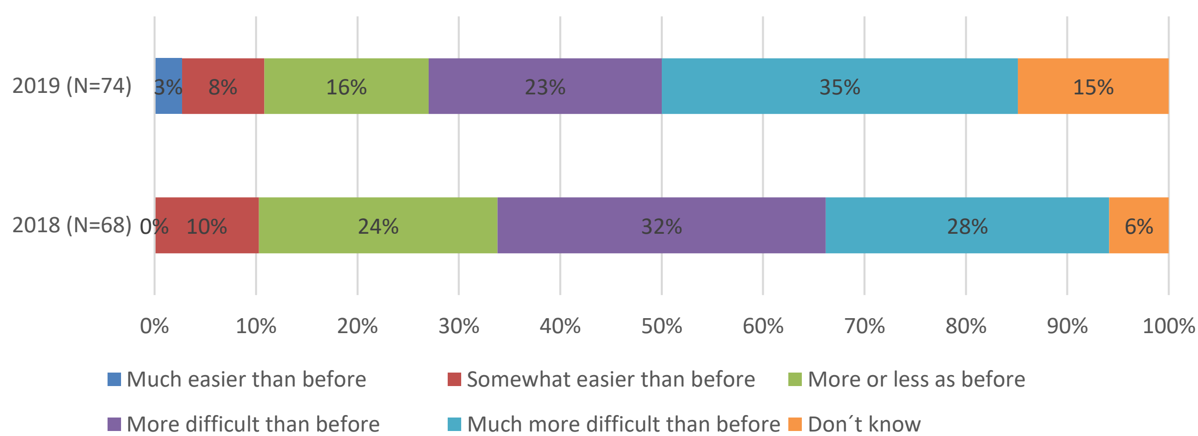


Source: Facsimile from Hagen et al. (forthcoming).

The situation for freight and distribution transport

The majority of truck drivers operating in the city centre are dissatisfied with the situation for freight and distribution in central Oslo in all years surveyed, although there was a weak tendency for drivers to be somewhat more satisfied in 2019 than before. Drivers experience challenges associated with too few loading and unloading areas and accessibility problems due to driving bans and one-way driving as the greatest challenges in the city centre.

Figure 14. "Is it easier or more difficult to find available space for loading and unloading after on-street parking spaces in Oslo city have been removed?"



Source: Facsimile from Hagen et al. (*forthcoming*).

The majority of drivers find that the goods delivery situation has worsened due to the changes in Oslo city centre. More drivers said that removing on-street parking in the centre had made it more difficult to find parking for loading and unloading in 2018 and 2019, see Figure 14.

This is despite the fact that several loading/unloading sites and approximately 125 parking spaces for commercial vehicles have been added or are under construction. Truck drivers also said that the changes in driving patterns mean increased time used on deliveries and longer driving distances. Among the proposals to authorities, drivers most frequently mentioned additional reserved spaces for deliveries.

Responses to other changes and to the totality of changes

A number of changes have taken place in the transport systems in Oslo in the period from 2015 to 2020 that have resulted in shifts in travel behaviour towards less car use. Continuous improvement of the public transport services in particular have led to increased vhkm travelled for public transport (Figure 2). In 2016, a new metro station opened, allowing for new and better connections and a large-scale reorganisation of the system. In 2015, a southern metro line closed down for rehabilitation and upgrading, and it reopened in the spring 2016. The city has introduced parking fees for on-street parking for the inner city, with higher fees city for visitors and lower fees for inhabitants. At the same time, many on-street parking spaces in the inner city have been removed to give room for bike lanes, allowing for defining nine prioritised and continuous bike routes through the inner city to the city centre, see illustrations in Figure 15. There has been rehabilitation works in seven other tunnels than those discussed above, causing temporary delays for road traffic. Road-tolls were significantly increased in 2017, and in 2019 an “inner toll ring” was introduced (after our survey was closed), to also toll those driving in the city, and the pricing system was changed.

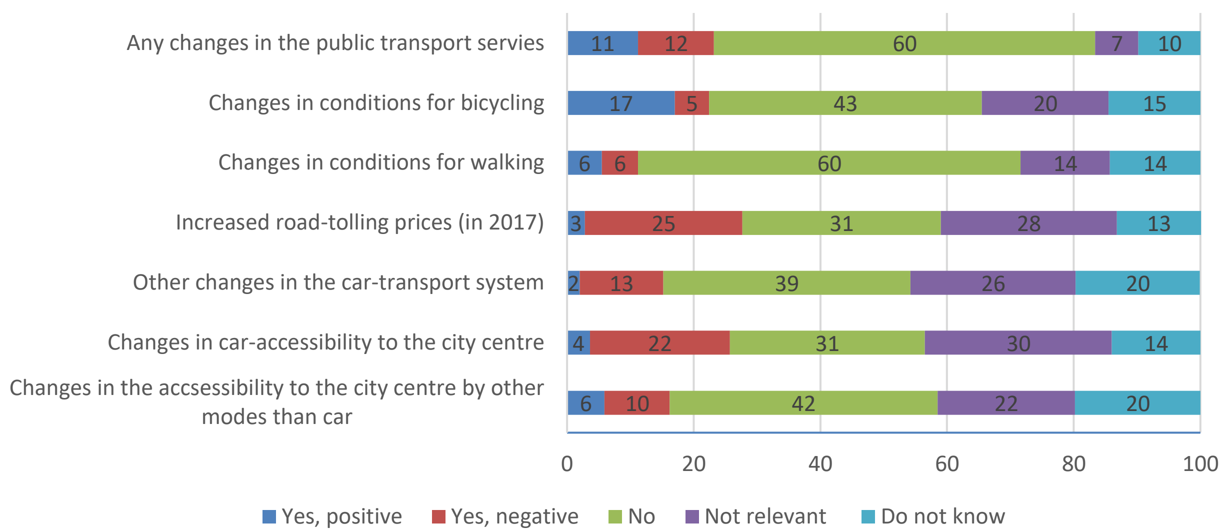
Figure 15. Map showing prioritised bicycle routes in Oslo Inner City, and photo illustrating the intervention where parking spaces have been reallocated to bicycle lanes.

Sources: Map from Municipality of Oslo, photo by Aud Tennøy.

The 2019 survey asked all respondents whether they experienced that any of the many changes in the transport systems had affected their commute, in either a positive or a negative way. Figure 16 charts their responses.

Results show that respondents in general find that most of the changes in the transport system either have not affected their commute, are not relevant for them or that they do not know. Still, many respondents have suggested improvements when offered the opportunity through open questions. The most negatively perceived changes for respondents’ commutes are increased road-toll prices and reduced accessibility to the city centre by car (and this latter finding make us suspect that some respondents expressed what they think about these changes rather than if they actually affected their commutes). It is interesting to note that improved conditions for bicycling are appreciated by 17% of the respondents, while only 5% see this as a negative change. About as many have experienced changes in the public transport system as contributing positively to their commute (11%) as negatively (12%).

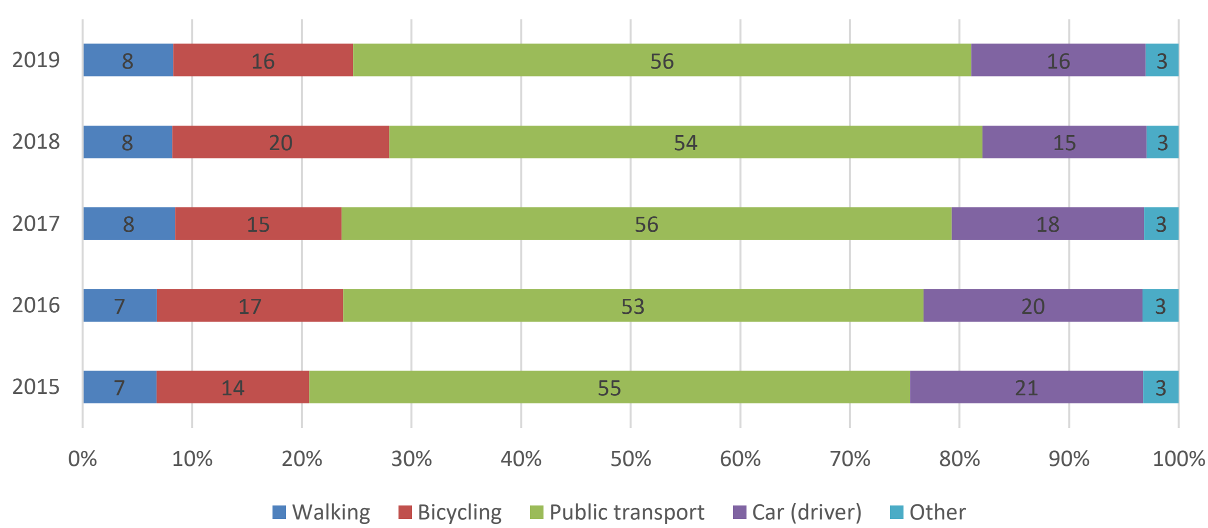
Figure 16. "Have any of the changes listed below affected your commute?" N=5421 (2019)



Source: Facsimile from Tennøy et al. (forthcoming).

When analysing surveys across all five years, from 2015 to 2019, there are significant shifts in travel behaviour, see Figure 17. The proportion answering that they drove a car last time they travelled to work reduced from 21% in 2015 to 16% in 2019, which is almost a 25% reduction. These surveys had a high number of respondents, varying from n = 4 270 in 2015 to n = 6 768 in 2016.

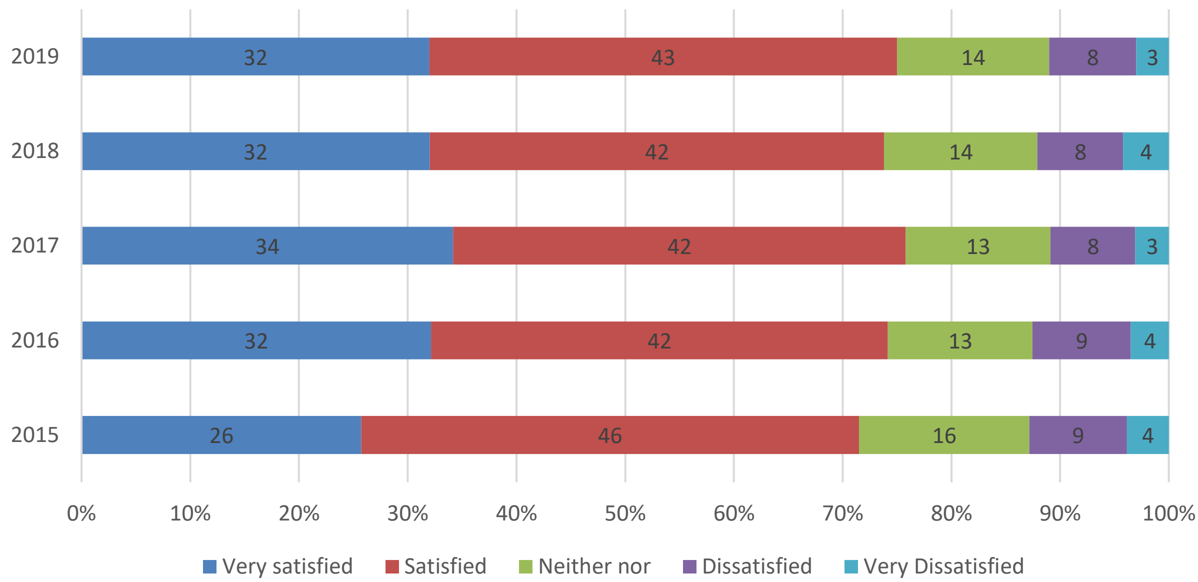
Figure 17. Modal shares among respondents, 2015 – 2019.



Source: Facsimile from Tennøy et al. (*forthcoming*).

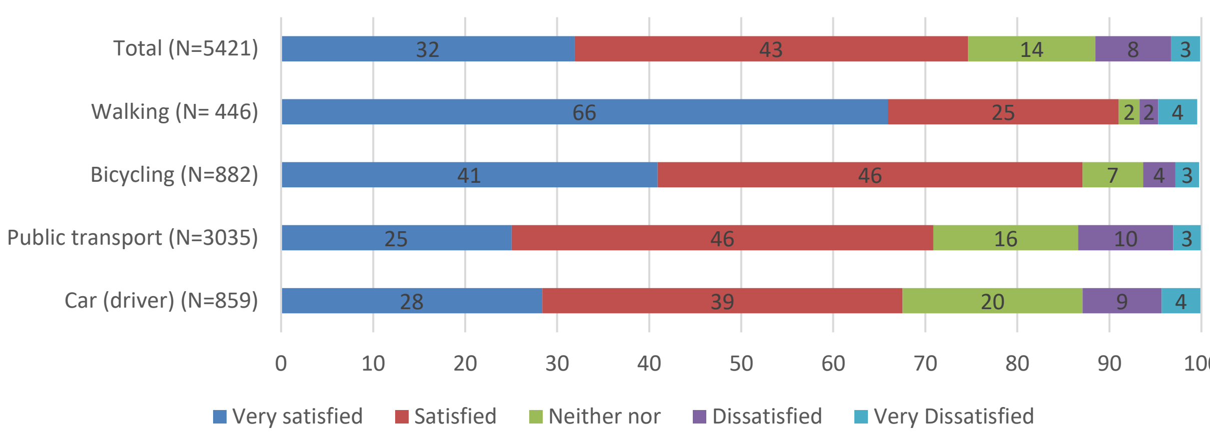
It is also an interesting finding that the respondents' satisfaction with their commute is quite stable, and slightly improved, through this five-year period, despite many changes in the transport system (see Figure 18). The proportion answering that they are satisfied or very satisfied with their commute (at this time of the year) varies from 72% in 2015 to 75% in 2017 and 2019. The proportion answering that they are dissatisfied or very dissatisfied varies from 11% (2017 and 2019) to 13% (2015 and 2016).

Figure 18. Satisfaction with commutes among respondents, 2015 – 2019.



Source: Facsimile from Tennøy et al. (forthcoming).

Figure 19. Satisfaction with commute, dependent of mode of transport, in 2019.



Source: Facsimile from Tennøy et al. (*forthcoming*).

When asked whether their commute has become better or worse compared to what it was one year ago, most respondents answer "unchanged" all years. The proportion answering worse or much worse varies from 16% (2018 and 2019) to 19% (2016). The proportion answering better or much better varies from 13% (2019) to 18% (2016 and 2017).

The analysis included who was most satisfied with their commute in 2019(Figure 19). Those walking are clearly most satisfied with their commute, followed by those using public transport and car drivers. Car-drivers and public transport users report being dissatisfied more often, but also among them only 13% report being dissatisfied.

The path forward

The BYTRANS project is ongoing. Researchers are still discussing the results and how they can be relevant in planning, decision-making and research. Below, findings are summarised and discussed with respect to how they can contribute to changes in urban planning and development. This is followed by a reflection around the prospects for Norwegian cities of achieving the zero-growth objective.

The implications

Common for all three cases presented here (capacity reduction in the Smestad and Bryn tunnel, changed accessibility to, and in, Oslo city centre), is that the effects and consequences of the changes in the transport system were less severe than expected. This is in accordance with theory and with previous empirical findings from studies of similar cases (Cairns et al. 1998, 2001; Goodwin 1996).

The Smestad tunnel turned out to have enough capacity for AADT 50 000 also with only two lanes, and the capacity reduction had only negligible effects. The most interesting thing about the case, is that this came as a surprise, as road authorities had expected that the capacity reduction would strongly increase congestion and delays. When the results were released to the public, many (mainly professionals) were reluctant to believe that the results could be correct. This led to interesting and relevant discussions. The issues discussed include: 1)actual versus theoretical maximum capacity of roads; 2) how road design and speed affect road capacity; 3) how and to what extent existing road capacity can be reallocated to, for instance, public transport or other uses; and 4) whether 'replacement capacity' is necessary if one decides to reallocate road space for other uses.

In the Bryn case, increased congestion and delays did occur, but effects and consequences were less severe than expected. The effects were limited to the tunnel and the road system in close proximity to the tunnel. Variability in the system increased, and this was a problem for road-users. Still, on average days, the extra delays were tolerable. Some road users adapted in various ways, while others travelled as before. The conclusion was that this went quite well, as the capacity reduction did not cause chaos, crisis or intolerable situations. This conclusion also caused debates. The question of defining tolerable congestions and delays was raised. In this debate, findings from analyses of how commuters have responded to the totality of changes in the Oslo transport system in the period 2015-2019 are interesting. The changes led to reduced car commuting and people are at least as satisfied with their commute in 2019 as they were in 2015. Overall, car commuters are satisfied. This raises questions concerning whether authorities, other professionals and policy-makers have over-rated the negative effects and consequences of congestion. If so, that could also be part of the explanation for negative responses to congestion charges lately, even though they have proven to reduce congestion.

Concerning access to, and inside Oslo city centre, this has not so far has affected how people travel to, and use, the city centre. Commuters travel as they used to, and are equally satisfied with their commutes. City centre users continue to use other modes than car when visiting the city centre, they find it easy to travel to the city centre. Those walking and biking have become more satisfied, while those driving have become less satisfied. So far, changes have not caused people to use the city centre more than before, but more people believe that the changes taking place will make people use the city centre (even) more. Freight and distribution truck drivers were dissatisfied in the before-situation, and say that the conditions for deliveries in the centre has worsened, despite the fact that facilitating for them has been a prioritised issue. Oslo city centre is still in the transformation phase, and we do not yet how the changes will affect the use of the city centre in the long run.

How, then, can this knowledge be useful for cities aiming at zero-growth or reduction in traffic volumes, while at the same time developing more attractive and liveable cities and urban regions, with vibrant and accessible city centres, and with efficient, safe and convenient mobility systems, where more of the transport is done by active modes, and where local and global pollution generated by transport is reduced?

In such discussions, it is problematic if those who are solving the problem have a too narrow and restricted understanding of what alternative solutions are possible and relevant. If one, for instance, sees removal of on-street parking as “not possible”, it will also be “not possible” to develop a continuous bicycle network through the inner city. If one sees reallocation of main road car lanes to public transport lanes as “not possible”, it might also be “not possible” to improve public transport speed and competitiveness, and make urban transport systems more efficient. Likewise, if one believes the city centre will become less vibrant if street space is reallocated from parking and driving to walking, bicycling, public transport and urban life, this is not a feasible alternative. We believe that the BYTRANS findings, and results from other similar cases, might help expanding the understanding of what are possible and relevant interventions. This might accelerate the implementation of measures that contribute to achieving prioritised goals, including the zero-growth objective.

Further, in discussions concerning implementation of interventions making mobility more sustainable, and where the suggested measures cause reduced car accessibility, it is often claimed that “replacement capacity” (could also be parking) needs to be in place first. Results from the BYTRANS project strongly question whether “replacement capacity” is necessary. Existing road capacity might be higher than expected, and there might be ways of increasing capacity by, for instance, reducing speed. The research results do also illustrate that people adapt to changes in the transport systems in different ways. This might strengthen an understanding around why expanding road capacity in congested urban transport systems contributes negatively to achieving sustainability goals, and hopefully it will contribute to stopping future urban road capacity expansions.

When analysing adaptations, effects and consequences for different users of the transport systems, the researchers are analysing which groups are more affected than others, and in what ways. So far, distribution truck drivers stand out as a group needing more attention. The researchers are in the process of analysing BYTRANS data with respect to such issues. They will produce knowledge that can be useful when making cities and transport systems more just and inclusive. This could also be a necessity, to avoid severe protests that could hamper development contributing to goal achievement.

Towards zero-growth in passenger traffic?

In 2015, the red-green political coalition in Oslo were loud and clear during the election campaigns that they would change the city in a more people-friendly and less car-friendly way. They were elected, and in the four years that have passed, they have initiated and implemented many of the changes they promised. The debates have often been loud. However, it seems that a majority of those living in Oslo have appreciated the changes, as the red-green City Government was re-elected in September 2019. We see similar tendencies also in other Norwegian cities. It seems that objectives concerning more attractive and liveable cities and zero-growth in traffic volumes have climbed up the urban planning agenda across Norwegian cities and counties (Tennøy and Øksenholt, 2018).

The strongest hindrance for achieving the zero-growth objective might be state-level actions. The national road authorities plan road capacity expansions in several Norwegian cities, including in the Oslo region (NPRA 2013, 2016) that will likely counteract the zero-growth objective. State activities, like hospitals, state offices, and police stations are being located in car-dependent areas causing traffic growth, which is not in accordance with national planning guidelines (Tennøy et al., 2017). It has also been documented that the current national government overrules regional authorities when they bring forward formal objections concerning municipal master plans and other plans that are not in accordance with the planning guidelines. This results in more transport demand and car-dependent land use development (Tennøy and Øksenholt, 2018).

Other hindrances for achieving the zero-growth objective could be protests from suburban municipalities experiencing strong restrictions on their land use development, and protests against increased toll roads from commuters to the main cities who live in these areas. During the 2019 election campaigns, these protests almost caused a change of government. Following this, and as part of making the next National Transport Plan, it is discussed whether the zero-growth objective is to be replaced by other objectives, for instance, concerning GHG emissions (only). It will be interesting to follow the development in Norwegian cites and urban regions the coming years.

Notes

1 Concerning land use development, national authorities prepare laws, white papers, regulations, policy guidelines, and other documents, to influence planning at lower levels. If formal objections are raised to a planning proposal, the Ministry of Local Government and Modernisation determines whether the plan can be adopted. Regional authorities develop and approve non-binding regional land use plans that "… form the basis for the activities of regional bodies and for municipal and central government planning and activities in the region" (PBA, chapter 8). Responsibilities for land-use planning and decision-making clearly lie at the municipal level, making and approving binding master plans for the municipality, and assessing and approving zoning plans. Land use development also concerns localisation of state, regional and municipal activities. According to national planning guidelines (Ministry of Local Government and Modernisation 2015), they are to be localised in ways reducing transport demand and facilitating use of other modes that the private car, for employees and for visitors. National authorities are responsible for planning, financing and implementing large transport infrastructure projects, for maintenance of railways and the most important national roads, and for railway services. Regional authorities are responsible for most national and regional roads and for local and regional public transport. Municipal authorities are responsible for local transport infrastructure, including regulation of parking access and fees.

References

Akershus County, Oslo Municipality (2015), *Regional plan for areal og transport i Oslo og Akershus* [Regional plan for land-use and transport in Oslo and Akershus], http://www.akershus.no (accessed: 14 July 2020).

Allen, J., et al. (2000), *A framework for considering policies to encourage sustainable urban freight traffic and goods/service flows*, summary report, University of Westminster, Westminster, http://home.wmin.ac.uk/transport/download/urbandistsumm.pdf, (accessed 15 July)

Asplan Viak (2008), *Evaluering av prosjekt "Gjennomgående kollektivfelt I Trondheim", (Project evaluation: Intengrated Public Transport in Trondheim)*, Asplan Viak, Asker og Trondheim https://www.vegvesen.no/_attachment/106733/binary/1274558?fast_title=Kollektivfelt+i+Trondheim+-+vedleggsrapport.pdf (access 22 July 2020).

Banister, D. (2008), "The sustainable mobility", *Transport Policy*, Vol. 15/2, pp. 73-80, https://doi.org/10.1016/j.tranpol.2007.10.005

Banister, D. (2011), "Cities, mobility and climate change", *Journal of Transport Geography*, Vol. 19(6), pp. 1538-1546, https://doi.org/10.1016/j.jtrangeo.2011.03.009.

Börjesson, M., et al. (2012), "The Stockholm congestion charges—5 years on. Effects, acceptability and lessons learnt", *Transport Policy*, Vol. 20, pp. 1-12, https://doi.org/10.1016/j.tranpol.2011.11.001.

Browne, M., et al. (2003), *A guide on how to set up and run Freight Quality Partnerships, Good Practice Guide on Urban Freight Transport*, BESTUFS Best Urban Freight Solutions, Rijswijk, www.bestufs.net/download/BESTUFS_II/good_practice/English_BESTUFS_Guide.pdf, (access 22 July 2020).

Bryson, J. M., B. C. Crosby and M. M. Stone (2015), "Designing and implementing cross-sector collaborations: Needed and challenging", *Public Administration Review*, Vol. 75(5), pp. 647-663.

Cairns, S., S. Atkins and P. Goodwin (2001), "Disappearing traffic? The story so far", *Municipal Engineer*, Vol. 1, pp. 13-22, http://contextsensitivesolutions.org/content/reading/disappearing-traffic/resources/disappearing-traffic/

Cairns, S., C. Hass-Klau and P. Goodwin (1998), *Traffic Impact of Highway Capacity Reductions: Assessments of The Evidence*, Landor publishing, London.

Carmona, M., et al. (2017), "Street appeal: The value of street improvements", *Progress in Planning*, Vol. 126, pp. 1-52, 10.1016/j.progress.2017.09.001.

Caspersen, E., T. Ørving and A. Tennøy (forthcoming), Urban road transport system disruptions: How can and do truck drivers adapt, and what effects and consequences do they experience?

Cervero, R. (2003), "Road expansion, urban growth, and induced travel: A path analysis", *Journal of American Planning Association*, Vol. 69/2, pp. 145-163, https://doi.org/10.1080/01944360308976303.

Committee on Trunk Road Assessments (1994), *Trunk Roads and the Generation of Traffic*, MSO, London.

Crum, M. R. and P. C. Morrow (2002), "The influence of carrier scheduling practices on truck driver fatigue", *Transportation Journal,* Vol. 42**,** pp. 20-41, https://www.jstor.org/stable/20713513?seq=1.

Downs, A. (2004), *Still Stuck in Traffic. Coping with Peak-hour Traffic Congestion*, Brookings Institution Press, Washington, DC.

Downs, A. (1962), "The law of peak-hour expressway congestion", *Traffic Quarterly*, Vol. 16, pp. 393-409, https://hdl.handle.net/2027/uc1.$b3477?urlappend=%3Bseq=457.

Duranton, G. and M. A. Turner (2011), "The fundamental law of road congestion: Evidence from U.S. cities", *American Economic Review*, Vol. 101, pp. 2616-2652, DOI 10.1257/aer.101.6.2616.

EU (2004), *Safety Requirements For Tunnels In The Trans-European Road Network,* Directive 2004/54/EC of the European Parliament and of the Council on minimum safety requirements for tunnels in the Trans-European Road Network, 29 April 20014, https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32004L0054.

EC (2011), *White Paper: Roadmap to a Single European Transport Area – Towards a Competitive and Resource Efficient Transport System*, Brussels, 28 March 2011, https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52011DC0144&from=EN.

EEA (2013), *A Closer Look at Urban Transport. TERM 2013: Transport Indicators Tracking Progress towards Environmental Targets in Europe*, EEA Report No. 11/2013, Copenhagen, doi: 10.2800/94848.

EEA (2018), *Trends and Projections in Europe 2018. Tracking Progress Towards Europe's Climate and Energy Targets,* EEA Report No. 16/218, EEA, Copenhagen, www.eea.europa.eu/publications/trends-and-projections-in-europe-2018.

Ewing, R. and S. Handy (2009), "Measuring the unmeasurable: Urban design quality related to walkability", *Journal of Urban Design*, Vol. 14(1), pp. 65-84, https://doi.org/10.1080/13574800802451155.

Fishman, E., S. Washington and N. Haworth (2014), "Bike share's impact on car use: Evidence from the United States, Great Britain, and Australia", *Transportation Research Part D: Transport and Environment*, Vol. 31, pp. 13-20, https://doi.org/10.1016/j.trd.2014.05.013.

Flyvbjerg, B. (1998), *Rationality and Power. Democracy in Practice*, University of Chicago Press, Chicago.

Forsyth, A. and K. Krizek (2010), "Promoting walking and Bicycling: Assessing the Evidence to Assist Planner", *Built Environment*, Vol. 36*,* pp. 429-446, http://kevinjkrizek.org/wp- content/uploads/2012/04/Bltenv.pdf.

Goodwin, P.B. (1996), "Empirical evidence on induced traffic. A review and synthesis", *Transportation*, Vol. 23, pp. 35-54, https://link.springer.com/article/10.1007/BF00166218.

Hagen, O.H., T. Ørving and A. Tennøy (forthcoming), *BYTRANS: Effects and Consequences of Changes in Oslo City Centre 2017 – 2019,* TØI-report XX/2020, Institute of Transport Economics, Oslo.

Hanssen, G. S., P. K. Mydske and E. Dahle (2013), "Multi-level coordination of climate change adaption: by national steering or by regional network governance?" *Local Environment*, Vol. 18(8), pp. 869-887, https://doi.org/10.1080/13549839.2012.738657.

Hull, A. (2005), "Integrated transport planning in the UK: From concept to reality", *Journal of Transport Geography*, Vol. 13(4), pp. 318-328, https://doi.org/10.1016/j.jtrangeo.2004.12.002.

Hull, A. (2008), "Policy integration: What will it take to achieve more sustainable transport solutions in cities?" *Transport Policy*, Vol. 15(2), pp. 94-103, https://doi.org/10.1016/j.tranpol.2007.10.004.

Hurlimann, A.C. and A. P. March (2012), "The role of spatial planning in adapting to climate change", *Wiley Interdisciplinary Review*, Vol. 3(4), pp. 477-488, https://doi.org/10.1002/wcc.183.

Ivanov, B., et al. (2008), *Storm-Related Closures of I-5 and I-90: Freight Transportation Economic Impact Assessment Report,* Washington State Department of Transportation Freight Systems Division, Seattle.

Litman, T. (2018), *Generated Traffic and Induced Travel. Implications for Transport Planning,* Version dated April 24 2018, Victoria Transport Policy Institute, Victoria, www.vtpi.org/gentraf.pdf.

Mayhew, C. and M. Quinlan (2006), "Economic pressure, multi-tiered subcontracting and occupational health and safety in Australian long-haul trucking", *Employee Relations,* Vol. 28**,** pp. 212229, doi 10.1108/01425450610661216.

McCoy, E.J. and D. A. Stephens (2014), "Quantifying causal effects of road network capacity expansions on traffic volume and density via a mixed model propensity score estimator", *Journal of the American Statistical Association*, Vol. 109/507, pp. 1440-1449, doi.org/10.1080/01621459.2014.956871.

Mesa-Arango, R. et al. (2013), *Estimating the Economic Impacts of Disruptions to Intermodal Freight Systems,* USDOT Region V Regional University Transportation Center Final Report, NEXTRANS Project No. 053PY03, West Lafayette.

Metz, D. (2017), "Valuing transport investments based on travel time saving: Inconsistency with United Kingdom policy objectives", *Cases Studies on Transport Policy*, Vol. 5/4, pp. 716-721, doi.org/10.1016/j.cstp.2017.07.003.

Ministry of Local Government and Modernisation (2008), *Lov om planlegging og byggesaksbehandling* (plan- og bygningsloven) [Law on planning and building regulations (Planning and Building Act https://lovdata.no (accessed 20 July 2020).

Ministry of Local Government and Modernisation (2014), *Statlige planretningslinjer for samordnet bolig-, areal- og transportplanlegging* [National planning guidelines for housing-, land use-, and transport planning], www.regjeringen.no (accessed 20 July 2020).

Ministry of Local Government and Modernisation (2012), *Meld. St. 21 (2011–2012). Norsk klimapolitikk* [White paper 21 (2011–2012). Norwegian Climate Politics], www.regjeringen.no (accessed 20 July 2020).

Ministry of Local Government and Modernisation (2015), *Nasjonale forventninger til regional og kommunal planlegging* [National expectations to regional and municipal planning], Decision made by Royal decree, June 12 2015, www.regjeringen.no (accessed 20 July 2020).

Ministry of Transport and Communications (2017), *Meld. St. 33 (2016–2017) Nasjonal transportplan 2018–2029* [White paper 33 (2016-2017) National Transport Plan 2018-2029], www.regjeringen.no (accessed 20 July 2020).

Ministry of Transport and Communications (2013), *Meld. St. 26 (2012–2013) Nasjonal transportplan 2014–2023* [White paper 26 (2012–2013) National Transport Plan 2014-2023], www.regjeringen.no (accessed 20 July 2020).

Mogridge, M. J. H. (1997), "The self-defeating nature of urban road capacity policy. A review of theories, disputes and available evidence", *Transport Policy*, Vol. 4/1, pp. 5-23, doi.org/10.1016/S0967-070X(96)00030-3.

Nadin, V. et al. (2018), *COMPASS – Comparative Analysis of Territorial Governance and Spatial Planning Systems in Europe*, Final report, Version 10 October 2018, ESPON EGTC, Luxembourg.

Næss, P. (2012), "Urban form and travel behavior: experience from a Nordic context", *Journal of Transport and Land-use*, Vol. 5/2, pp. 21-45, doi.org/10.5198/jtlu.v5i2.314.

Næss, P., et al.. (2013), "Knowledge-based land use and transport planning? Consistency and gap between 'state-of-the-art' knowledge and knowledge claims in planning documents in three Scandinavian city regions", *Planning Theory & Practice,* Vol. 14/4, pp. 470-491, www.tandfonline.com/doi/pdf/10.1080/14649357.2013.845682?needAccess=true.

Næss, P., et al. (2011), "On their road to sustainability? The challenge of sustainable mobility in urban planning and development in two Scandinavian capital regions", *Town Planning Review*, Vol. 82, pp. 285-315, doi 10.2307/27976000.

Næss, P., et al. (2019), "Residential location, commuting and non-work travel in two urban areas of different size and with different center structure", *Progress in Planning*, Vol. 128, pp. 1-36, dx.doi.org/10.1016/j.progress.2017.10.002.

Nævestad, T.O., I.S. Hesjevoll and R. O. Phillips (2018), "How can we improve safety culture in transport organizations? A review of interventions, effects and influencing factors", *Transportation Research Part F: Traffic Psychology and Behaviour,* Vol. 54**,** pp. 28-46, https://doi.org/10.1016/j.trf.2018.01.002

Newman, P.and Kenworthy, J. (1989), *Cities and Automobile Dependence. An International Sourcebook*, Gower, Aldershot..

Newman, P.and J. Kenworthy, J. (2015), *The End of Automobile Dependence. How Cities are Moving Beyond Car-Based Planning*, Island Press, Washington DC., doi.org/10.5822/978-1-61091-613-4_7.

Noland, R.B.and L. L. Lem (2002), "A review of the evidence for induced travel and changes in transportation and environmental policy in the US and the UK", *Transportation Research Part D, Vol. 7*/1, pp. 1-26, www.its.ucla.edu/wp-content/uploads/sites/2/2015/04/Replogle-Induced-TR-D.pdf.

Norwegian Environment Agency (2015), *Miljøstatus – Miljøinformasjon fra offentlige myndigheter* [Status of the Environment - Environmental information from public authorities], Norweigian Environment Agency, Oslo https://miljostatus.miljodirektoratet.no/.

Norwegian Public Roads administration (2013), *E18-korridoren Lysaker-Slependen. Kommunedelplan med KU* [E18-corridor Lysaker-Slependen. Municipal plan and Environmental Impact Assessment], Norwegian Public Roads administration, Oslo, https://www.vegvesen.no/_attachment/490475/binary/799592?fast_title=NB+-+13MB++E18+gjennom+Vestkorridoren.+Grunnlag+for+kommunedelplan.pdf (accessed 24 September 2020).

Norwegian Public Roads Administration (2016), *Planprogram. E6 Manglerudprosjektet*. [Planning program for the E6 Manglerud project],, Norwegian Public Roads Administration, Oslo https://www.vegvesen.no/_attachment/1575964/binary/1139826?fast_title=Planprogram+E6+Manglerudprosjektet+2016.pdf (accessed 25 September 2020).

Rode, P. et al., (2017), "Accessibility in Cities: Transport and Urban Form", in Meyer G. and S. Shaheen (eds.), *Disrupting Mobility. Lecture Notes in Mobility*, Springer International Publishing, Cham.

Ruter (2019), *Annual report for Ruter 2018*, https://aarsrapport2018.ruter.no/no/intro (accessed 21 July 2020).

Speck, J. (2012), *Walkable City. How Downtown Can Save America, One Step at a Time*. North Point Press, New York.

Statistics Norway (2019), *Table 11342, Land and population in municipalities, counties and the country (K) 2007-2019*, www.ssb.no/statbank/table/11342, (accessed 06 August 2020).

Stead, D. and E. Meijers (2009), "Spatial planning and policy integration: Concepts, facilitators and inhibitors", *Planning Theory & Practice*, Vol. 10/3, pp. 317-332, https://doi.org/10.1080/14649350903229752.

Tennøy, A. (2010), "Why we fail to reduce urban road-traffic volumes: Does it matter how planners frame the problem?" *Transport Policy*, Vol. 17, pp. 216-233, doi/10.1016/j.tranpol.2010.01.011.

Tennøy, A. (2012), "How and why planners make plans which, if implemented, cause growth in traffic volumes. Explanations related to the expert knowledge, the planners and the plan-making processes", PhD thesis, January 2012, Norwegian University of Life Sciences, Ås. DOI 10.13140/RG.2.1.1818.8326 .

Tennøy, A., et al. (2019c), "Effects and consequences of capacity reduction in the Bryn tunnel*"*, Documentation report, TØI-report 1733/2019, Norwegian Institute of transport Economics, Oslo.

Tennøy, A., J. U. Hanssen and K. V. Øksenholt (2019b), "Developing a tool for assessing park-and-ride facilities in a sustainable mobility perspective", *Urban, Planning and Transport Research,* Vol. 8/1, pp. 1-23, DOI 10.1080/21650020.2019.1690571.

Tennøy, A., et al. (2016), "How planners' use and non-use of expert knowledge affect the goal achievement potential of plans: Experiences from strategic land-use and transport planning processes in three Scandinavian cities", *Progress in Planning,* Vol. 109*,* pp. 1-32, https://doi.org/10.1016/j.progress.2015.05.002.

Tennøy, A.,et al. .(2017), "Localisation of national public sector enterprises – where and why?",*TØI-report 1576/2017,* Institute of Transport Economics, Oslo..

Tennøy, A. and K. V. Øksenholt (2018), "The impact of changed structural conditions on regional sustainable mobility planning in Norway," *Planning Theory & Practice*, Vol. 19/1, pp. 93-113,https://doi.org/10.1080/14649357.2017.1408135

Tennøy, A., A. Tønnesen and F. Gundersen (2019a), "The effects of urban road capacity expansions – Experiences from two Norwegian cases". *Transportation Research Part D: Transport and Environment*, Vol.69, pp 90-106, https://doi.org/10.1016/j.trd.2019.01.024

Tennøy, A. et al. (2015), *Pilotstudier: Før- og underveisundersøkelser av Smestadtunnelen og Østensjøbanen (Preliminary evaluation of the Baltic Sea Line and the Smestad Tunnel),* TØI-rapport 1455/2015, Institute of Transport Economics, Oslo., https://www.toi.no/publikasjoner/pilotstudier-for-og-underveisundersokelser-av-ostensjobanen-og-smestadtunnelen-article33725-8.html (accessed 24 September 2020).

Tennøy, A., et al. (2016), "Experiences with capacity reductions on urban main roads – Rethinking allocation of urban road capacity?", *Transportation Research Procedia,* Vol. 19*, pp.* 4-17, https://doi.org/10.1016/j.trpro.2016.12.063.

Tennøy et al. (forthcoming 2020), "BYTRANS: Effects and consequences of changes in the Oslo transport system 2015-2019", TØI-report XX/2020, TØI-rapport 1455/2015, Institute of Transport Economics, Oslo.

Tønnesen, A., O. H. Hagen and A. Tennøy (*in review*), When tunnel maintenance enters the urban limelight – The use of public information in road capacity-reductions.

Tønnesen, A., et al.. (2019), "BYTRANS: Informasjonsarbeid ved rehabilitering av Østensjøbanen, Smestad- og Brynstunnelene*" (BYTRANS: Information campaigns during rehabilitation of Østensjøbanen, Smestadtunnelen and Brynstunnelen),* TØI rapport 1694/2019, Institute of Transport Economics, Oslo.

Tønnesen, A., J. R. Krogstad and P. Christiansen (2019), "National goals and tools to fulfil them- A study of opportunities and pitfalls in Norwegian metagovernance of urban mobility", *Transport Policy*, Vol. 81: pp. 35-44, DOI: 10.1016/j.tranpol.2019.05.018

Torp, A. and T. Eriksen (2009), *Trafikkregistreringer før og etter trafikkomlegging i Bjørvika/E18 Festningstunnelen (Traffic evaluation before after reduced road capacity on E18 Festningstunnelen).* PROSAM notat.

Twitchett, C. (2013), *Ignoring Induced Traffic – An Empirical Study of Induced Traffic.* Master thesis, Aalborg University, Aalborg..

UN Habitat (2013), *Planning and Design for Sustainable Urban Mobility. Global Report on Human Settlements 2013,* Routledge, New York.

Verma, A. (2018), "Shifting focus from supply to demand – The changing face of transportation towards sustainability", in Gautam A., S. De, A. Dhar, J. Gupta J. and A. Pandey (eds.), *Sustainable Energy and Transportation. Energy, Environment, and Sustainability*, Springer, Singapore, doi.org/10.1007/978-981-10-709-4_2.

Wägener, M. and F. Fürst (2004), "Land use and transport interaction: State of the art", Universität Dortmund, Fakultät Raumplanung, Dortmund, DOI 10.2139/ssrn.1434678 .

Walker, J. (2012), *Human Transit. How Clearer Thinking about Public Transit Can Enrich Our Communities and Our Lives,* Island Press, Washington D. C.

Wolday, F., A. Næss and A. Tønnesen (2019), "Workplace location, polycentrism and car commuting",. *Journal of Transport and Land Use,* Vol. 12,/1, pp. 78-810, https://doi.org/10.5198/jtlu.2019.1488.

Reallocation of Road and Street Space in Oslo

Measures for Zero Growth in Urban Traffic

This paper discusses Norway's zero-growth objective for passenger car traffic. It focuses on Oslo's experience with removing parking space, improving walking and cycling conditions and reducing road capacity on main motorways. The paper highlights the effectiveness of reallocating road and street space to achieving more sustainable uses, reducing car-dependency and lowering traffic volumes.

All resources from the Roundtable on Zero Car Growth? Managing Urban Traffic are available at: www.itf-oecd.org/zero-car-growth-managing-urban-traffic-roundtable.

International Transport Forum
2 rue André Pascal
F-75775 Paris Cedex 16
+33 (0)1 73 31 25 00
contact@itf-oecd.org
www.itf-oecd.org

Published: 10/2020 | Photo credit: gabriel12/Shutterstock