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Effects of urban road capacity expansion – Experiences from two Norwegian cases

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ABSTRACT

This article presents nuanced and context-related empirical research on the traffic-inducing effects of urban road capacity expansion two Norwegian cities. It focusses on the indirect and long-term land-use effects and on land-use planning and policies, that are not well covered in existing literature. Unsurprisingly, results show traffic-inducing land-use development in the period after the road capacity expansions. Differences in planning policy and practices affected how traffic-inducing the land-use development was. The traffic growth was stronger in the affected road corridors than expected, and as compared with Norway. No or only short-term congestion relief was found. It is concluded that the road capacity expansions were necessary conditions for the land-use sprawl, and consequently, contributing causes for the traffic growth. Ex-ante analyses seem not to have included the land-use effects, and this is understood as part of the explanation for the discrepancies between ex-ante expectations and actual development. In both cases, municipal and regional authorities currently attempt to steer land use development in directions contributing to stop traffic growth, in accordance with national policies. Meanwhile, road authorities plan for new capacity expansions in the investigated corridors. Land use effects of the capacity expansions seem, again, not to be included in the assessments.

1. Introduction

Reducing traffic growth and greenhouse gas (GHG) emissions from transport are long-held objectives in many countries and cities, but they have proven to be difficult to achieve (European Environment Agency, 2018; European Commission, 2011; Owens and Cowell, 2002; Norwegian Environment Agency, 2015; UN Habitat, 2013). These objectives are also high on the agenda in the Norwegian Parliament's climate agreement and the National Transport Plan, as well as in many regional and municipal plans. According to these policy documents, increasing transport demands caused by the rapid population growth in Norwegian urban regions should not cause growth in road-traffic volumes, and this is often termed the *zero-growth objective* (Ministry of Local Government and Modernisation, 2012, Ministry of Transport and Communications, 2013, 2017). Other motivations for zero-growth than reducing GHG emissions are improving urban transport efficiency, liveability, public health and the local environment, as well as reducing congestion and the need for infrastructure investments.

Achieving the zero-growth objective, as the population in the urban region grows, requires that the average inhabitant reduces his or her average daily traffic volume by making fewer trips, shorter trips and/or a lower share of trips as a car driver. A main strategy for achieving this is developing land-use and transport systems in directions contributing to reduced transport demand and shifts in the modal split toward less car usage (Ministry of Local Government and Modernisation, 2015). This strategy largely leans on

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theoretical and empirical knowledge concerning how and why the spatial structure (Hurlimann and March, 2012; Newman and Kenworthy, 1989, 2015; Næss, 2012; Næss et al., in press; Rode et al., 2017), as well as absolute and relative qualities of the transport-systems (Cairns et al., 2001; Downs, 1962, 2004; Fishman et al., 2014; Litman, 2018; Noland and Lem, 2002; Walker, 2012), affect travel behaviour and traffic volumes. Based on such insights, there seems to be a relatively widespread agreement on how land-use and transport systems ought to be developed to reduce or delimit urban road-traffic volumes: (i) land-use development as central, urban densification and transformation rather than sprawl; (ii) improving public transport services and conditions for walking and bicycling; (iii) physical and fiscal restrictions on private car traffic (see, for instance, Downs, 2004; Banister, 2008; Newman and Kenworthy, 2015; Rode et al., 2017; Tennøy, 2012). This understanding also includes that expanding road capacity in pressured urban road systems has traffic-inducing effects and contribute to traffic growth that would otherwise not occurred (as we discuss below).

It is an interesting paradox that road capacity expansions currently are planned and constructed in cities across Norway, despite the strong focus on the zero-growth objective, and that Norwegian planners know about the traffic-inducing effects of road capacity expansions (Tennøy, 2010, 2012). Previous research has found that this among other things can be explained by fragmented organization and the power distribution in land-use and transport planning and policy, combined with goal conflicts (e.g. Flyvbjerg, 1998; Bryson et al., 2015; Hull, 2008; Stead and Meijers, 2009; Tennøy and Øksenholt, 2018; Tønnesen, 2015), and deficiencies of transport model and cost benefit analyses (see e.g. Flyvbjerg et al., 2005; Litman, 2018; Metz, 2017; Cervero, 2003; Næss et al., 2012; Nicolaisen and Næss, 2015; Tennøy et al., 2006), which are not in focus here. Another strand of research suggest that the ways planners acquire and use knowledge when making plans, could be part of the explanation (Krizek et al., 2009; Næss et al., 2013; Tennøy et al., 2016). Tennøy (2012) found that even though planners *knew of*, for instance, mechanisms involved in induced traffic, few knew and understood this deep and well enough to use the knowledge in planning and tough discussions, or to explain the complex and often counter-intuitive interrelations between transport systems development, land-use, travel behaviour, traffic volumes and congestion to political decision makers and others. Planners seldom read up on research-based knowledge, and they explained that this was partly due to lack of what they perceived as understandable, relevant and applicable research and documentation. Previous studies on induced traffic mainly rely on aggregated statistical analyses or modelling (see, e.g. Noland and Lem, 2002 or Litman, 2018 for reviews), that are not necessarily easily accessible or useful in planning practice and policy making. Further, few previous studies include land-use effects of capacity expansions. As a result, this knowledge is often ousted or disregarded in planning and decision-making processes (Næss et al., 2013; Tennøy, 2012; Tennøy et al., 2016), as also found in recent analyses and plans relevant in this article (National Public Roads Administration (NPRA), 2013a, 2013b, 2016a).

The aim of this article is to contribute to existing literature with more nuanced and context-related empirical investigations of traffic inducing effects of road capacity expansions in pressured urban road systems, focusing on the less researched land-use effects, and including reflections on how differences in land-use planning and policy affect interrelations and development. Through analyses of longitudinal empirical data in two cases of urban road capacity expansions, as well as document studies and interviews with relevant practitioners, we present more disaggregated analyses of the mechanisms involved than most previous studies have done. We think our analyses and findings also have the potential to inform practitioners and policymakers about how road capacity expansions affect land-use, travel behaviour, and traffic, as well as the implications for land-use and transport planning if sustainability goals are to be achieved, possibly resulting in these mechanisms being more consciously addressed in future analyses and plans. We also discuss alternative policy responses to congestion and perceived demand for road capacity expansions, based on findings concerning current planning and ideas in the case cities.

We seek to answer the following research questions: *How have urban road capacity expansions affected land-use development, consequently affecting traffic volumes and congestion levels, in the cases? How have land-use planning and policy affected the land-use effects of road capacity expansions? How do road capacity expansions affect the potential to stop traffic growth in urban areas?*

The article is organised as follows: Section 2 presents the theoretical understandings forming the basis for the empirical investigations and analyses, while Section 3 delineates the research design, methods, data, and the main challenges experienced. Section 4 describes the two cases and results. The main conclusions are presented in Section 5, followed by a discussion of the significance of the results.

2. How urban road capacity expansions affect traffic volumes

Previous research has presented explanations and evidence on how road capacity expansions in pressured urban road systems induce traffic, and contribute to traffic growth that would otherwise not have occurred (see, e.g. Cairns et al., 2001; Cervero, 2003; Committee on Trunk Road Assessments, 1994; Downs, 1962, 2004; Duranton and Turner, 2011, Goodwin, 1996; Litman, 2018; McCoy and Stephens, 2014; Mogridge, 1997; Noland and Lem, 2002). This is understood as being the result of combined mechanisms, working at different time scales, where the interactions between land-use development, transport-systems development and travel behaviour play important roles.

Direct mechanisms, which may be *activated almost immediately* and often strengthened later on, are modal shifts from other modes to cars when travelling by car becomes relatively faster, more comfortable and so on compared with other modes of transport, and longer car journeys as time and cost of travel per km are reduced. These mechanisms are well understood and documented (see, e.g. Cairns et al., 2001; Committee on Trunk Road Assessments, 1994; Downs, 1962; Goodwin, 1996; Mogridge, 1997; Noland and Lem, 2002; Twitchett, 2013), so we do not focus on them. Instead, we focus on the less investigated *indirect land-use mechanisms*, working in a *longer time perspective.* As illustrated in Fig. 1, these include that road capacity expansions in congested urban road systems result in reduced travel time by car, triggering relocations of households and businesses in existing built structures in more transport-

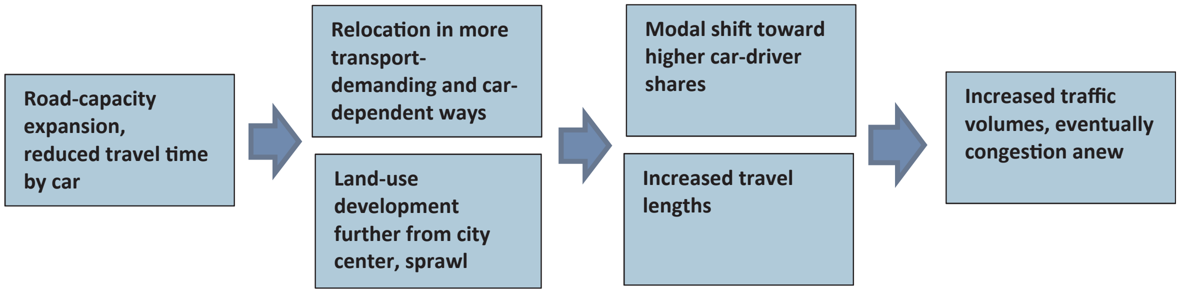


Fig. 1. Illustration of mechanisms involved when urban road capacity expansions cause more transport-demanding and car-dependent land-use development, resulting in higher car shares, longer journeys and increased traffic volumes per capita and in total.

demanding and car-dependent ways, as well as increased pressure on developing housing, workplaces, retail and so on at the outskirts of cities and urban regions (Cervero, 2003; Downs, 2004; Noland and Lem, 2002; Wägener and Fürst, 2004). This is a development toward more sprawled and car-dependent urban areas, causing modal shifts towards higher car-driver shares and increased travel lengths, and consequently to increased traffic volumes (vehicle kilometres, vhkm) per capita and in total (Næss et al., in press; Newman and Kenworthy, 2015).

In urban areas with high potential for sprawl, these processes continue until traffic growth causes renewed congestion, reducing the attractiveness of development in the more peripheral urban areas and making the private car less competitive as a mode of transport. This is also a situation where there are 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 or other infrastructure investments to ease congestion and improve accessibility.

How the mechanisms play out depends on land-use planning and policy. To a large extent, land-use development is steered by public authorities, in Norway as in most European countries, although the market decides what is built and when within the limitations of the plans decided by the authorities (Nadin et al., 2018; Owens and Cowell, 2002; Tennøy and Øksenholt, 2018). The land-use effects of road capacity expansions will hence be influenced by public land-use planning and policies. If planning authorities limit growth in peripheral urban areas and steer land-use development toward dense structures in areas with good access to daily services and competitive public transport accessibility, the traffic-inducing effects of road capacity expansions are expected to be weaker than if planning authorities allow strong, sprawled and car-dependent land-use development in peripheral urban areas. We investigate land-use planning and policies, as well as how these affected development, in our cases.

Diverted traffic, that is, shifts in timing and routes, may increase traffic volumes on expanded roads and concentrate more traffic to rush hours, contributing to increase congestion without being induced traffic (Downs, 2004). Other mechanisms, such as changes in economy, demography and road tolling, also affect traffic volumes (see, e.g. Downs, 2004; Noland and Lem, 2002), but we do not focus on these mechanisms in our study.

3. Research design, methodology and data

The research questions, together with the multi-causal nature of the problem, and our focus on investigating the mechanisms involved, call for in-depth case studies, longitudinal studies and a mixed-methods approach (Yin, 2003). We selected two cases of urban road capacity expansions in pressured urban road systems for our study. One is located in the medium-sized city (in a Norwegian context) of Ålesund, with 46 000 inhabitants, which is the main city in its region. The other is located in the Norwegian capital, Oslo, with about 700 000 inhabitants in the municipality and about 1 000 000 inhabitants in the city region. In aspects other than city size, the cases share similarities: The roads are located in the outer parts of the cities and reducing congestion and traffic on parallel roads were important motivations for constructing them. Thus, they could be understood as the same *type* of road capacity expansions. Our aims were to investigate how the mechanisms studied act out in these different contexts, as well as how conditions related to land-use planning and policies affect this. We were also inspired to include a case in a medium-sized city because we knew that that research in and on small and medium-sized cities is scarce. Due to differences in city size, the Ålesund case is analysed at the city level, while the Oslo case is considered at the regional level.

The road constructions were completed in 2002 (Ålesund) and 2009 (Oslo), which we expected would be far enough back in time for studying the long-term and indirect land-use effects of road capacity expansions, and at the same time, recent enough to allow access to data before, during and after the road capacity expansions and for doing longitudinal analyses. The effects of the mechanisms discussed in Section 2 were empirically investigated and analysed in each case, using multiple qualitative and quantitative data sources and methods, before they were compared in an analytical discussion.

The main data sources were register data of various kinds, documents and interviews. *Documents*, mainly plans and analyses related to the road projects, municipal and regional master plans, and 13 semi-structured *interviews* with knowledgeable practitioners (eight in the Ålesund case and six in the Oslo case; see list of interviewees in Appendix A and interview guide in Appendix B), provided data concerning motivations for the road projects and the context in which they were implemented. These sources were also important when describing land-use planning regimes and practices in relevant municipalities before and after the road capacity expansions, as well as how the current situation is perceived. *Traffic data* from the Norwegian National Road Administration (NPRA) were used for analysing changes in traffic volumes and congestion levels. *National Travel Survey data*, comprising reports from about 60 000 persons nationwide, were used in analyses of changes in modal splits (Hjorthol et al., 2014). *Register-based commuting statistics* at the census tract level from Statistics Norway (SN, 2016) were used in analyses of changes in commuting distances, and all commutes shorter than 200 km were included. The commuting statistics included all commutes, regardless of transport mode. *Geo-coded data* from the Central register of enterprises (SN, 2017a), including all units in Norway with economic activity, were used when analysing the number of workplaces in different areas, while *population statistics* (SN, 2017b) were employed when analysing population development.

The main challenges in this study were data availability and to clearly define whether the identified changes were effects of the road capacity expansions. Data from SN (2016, 2017a, 2017b) were available only back to 2001, 2002 and 2002 respectively, meaning that we could not identify potential significant changes in trends caused by the capacity expansions. Several of the interviewees were active when the plans for road capacity expansions were made, but this was a long time ago, so they could not answer all our questions in detail. The other interviewees were not involved at the time, but they could answer questions concerning policy and development after the road capacity expansions. For both cases, establishing reliable reference cases, preferably other road corridors in the same cities, proved difficult, mainly because potentially comparable corridors were affected by the road project and/or other major changes. We decided to use the general development in Norway as reference, to rule out potential significant effects of changes in national economy, taxes, regulations, and the like on traffic and land-use development. In the analyses, distinguishing clearly between the causal effects of the road capacity expansions and effects of 'other things going on' is problematic. This is a recurrent problem when studying interrelations between land-use development, development of transport-systems, travel behaviour and traffic volumes, since they are influenced by each other and other factors of different kinds. The need for longitudinal studies to capture the long-term and indirect mechanisms, often going decades back in time, enhances this problem. These challenges reduce the precision and strength of our findings. We still find that the study provides novel, interesting and more nuanced insights into mechanisms that have not been well covered in previous research, which is also relevant for researchers and practitioners striving to facilitate sustainable urban mobility.

4. Results

4.1. The Ålesund case

4.1.1. Case description

The Ålesund case involves a road capacity expansion at the outer parts of the city. A two-lane tunnel was built in 2002, in parallel to the existing two-lane road (E39) linking the city to its hinterland, thereby increasing the capacity from two to four lanes. In addition to the road tunnel that is our case, the road system in the nearby 'Moa area' was upgraded and improved, with a short tunnel, several roundabouts and pedestrian crossings. The projects were expected to reduce severe rush hour congestions expected to worsen due to population and traffic growth; reducing traffic on the existing road; and facilitating housing and retail development (Ålesund Municipality, 1993, 2001). It was thought that the planned new road system would have substantial capacity reserves for handling future traffic growth. 30% traffic growth was used in the calculations, but the documents available do not mention which year this

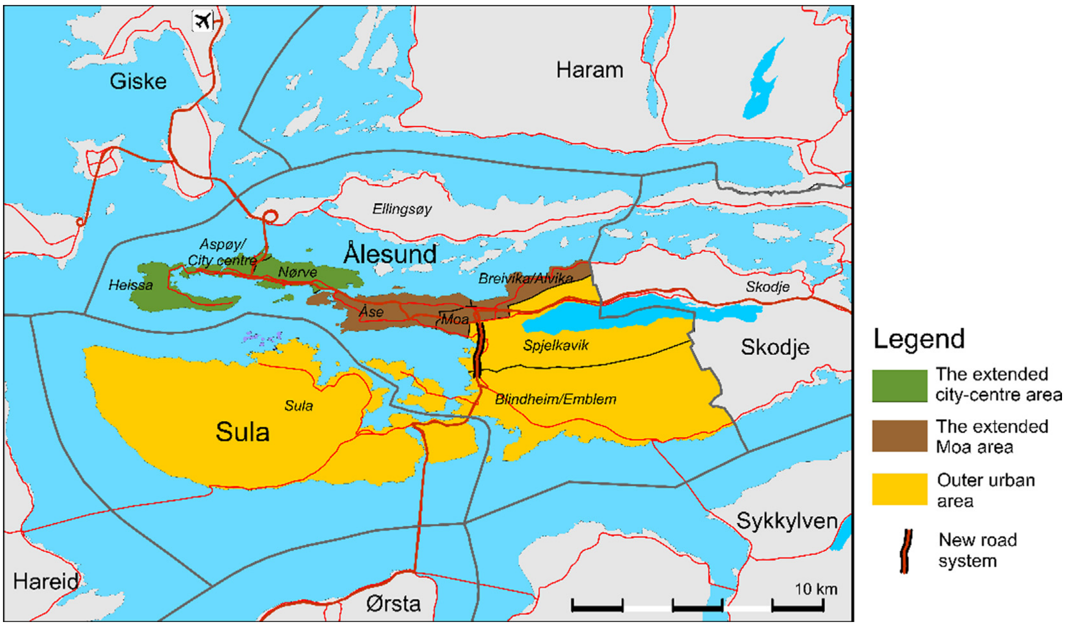


Fig. 2. Ålesund case. Overview, zones and location of the new tunnel.

Table 1
Population within geographic zones.
Source: Statistics Norway (2017b).

Area	Population 2002	Population 2009	Population 2016	Changes 2002–2009	Changes 2009–2016	Changes 2002–2016	Change (%) 2002–2016
Extended city centre area	15 268	15 844	17 218	576	1374	1950	12.8
Extended Moa area	11 027	11 759	12 892	732	1133	1865	16.9
Outer urban area	18 329	20 446	22 862	2117	2416	4533	24.7
Ålesund area total	44 624	48 049	52 972	3425	4923	8348	18.7
Norway total							15.2

refers to.

When analysing this case, we compared three main geographical zones, as illustrated in Fig. 2. The *outer urban area* is located upstream from the main bottleneck in the road system in the 'before' situation, and it was expected to benefit the most from the road capacity expansion. The *extended Moa area* was expected to benefit from improvements in the transport system in the Moa area, while, the *extended city centre area* was not expected to benefit directly from these projects.

4.1.2. Land-use development, planning and policy

When analysing land-use development in Ålesund from 2002 to 2016, we find a clear sprawling tendency, with higher percentages of inhabitants living in areas located farther from the main city centre in the 'after' than in the 'before' situation. The relative population growth is weakest in the extended city centre area and strongest in the outer urban area (see Table 1). 67% of the new housing units built in the period 2007–2017 were detached houses and rowhouses, while 33% were flats in apartment buildings (SN, 2018a).

We find similar tendencies when analysing the location of workplaces. The extended city centre area experienced far less growth than the other areas did in the period of 2002–2016 (see Table 2). The growth was strongest in the extended Moa area. The outer urban area also experienced a strong growth in number of jobs. As a result, the percentage of workplaces located in the extended city centre area decreased from 48% in 2002 to 41% in 2016. Further, retail studies revealed a strong increase in the Moa area's share of turnover, and a clear decrease in the city centre, between 2004 and 2012 (Dalen and Lynum, 2014). Moa has grown to become the third largest shopping-destination in Norway (NPRA, 2013a).

The statistics above describe a situation with a strong growth in population and workplaces at the outskirts of the urban area in the period after completion of the road capacity expansion, and most housing is built with rather low densities (detached houses and rowhouses), which we understand as a sprawling tendency. There are clear indications of causal relations between the road capacity expansion and the land-use development. Facilitating growth in the extended Moa area and the outer urban area was an argument for constructing the new tunnel, and increased pressure for constructing new housing in these areas was expected (Ålesund Municipality, 2001). This understanding is confirmed by the interviewees (planning authorities and developer), describing a 'before' situation where road authorities would make formal complaints if developers or municipal authorities suggested developments that would worsen congestion, while this was no longer an issue after the capacity expansion. The interviewees stated that the changed traffic situation, together with the shifts in location patterns, also seems to have triggered a trend of relocating offices from the city centre to an area adjacent to Moa, mainly to buildings previously used for other activities.

The interviews with planning authorities and the developer confirm that there has been a strong, steady pressure for constructing new housing and workplaces in the extended Moa area and the outer urban area in the period after the road capacity expansion. Planning authorities have not restricted this development or steered it in directions contributing to keep transport demand and car dependency low. In the interviews, the developers claim that lack of suitable building sites and high property prices in central urban areas left them no alternatives for large developments than the outer urban areas, and politicians wanted to facilitate population growth. Some of the land-use changes were not planned or expected, as in the relocation of offices from the city centre. The strong growth in work-places in the outer urban area was not mentioned in the municipal plans, and the figures suggested for expected population growth were more modest than shown by our data.

Table 2
Number of workplaces within geographic zones.
Source: Statistics Norway (2017a).

Area	Employees 2002	Employees 2009	Employees 2016	Change 2002–2009	Change 2009–2016	Change 2002–2016	Change (%) 2002–2016
Extended city centre area	11 218	11 667	11 795	450	128	578	5.1
Extended Moa area	5949	7393	8722	1444	1329	2773	46.6
Outer urban area	5980	7833	8144	1854	311	2164	36.2
Ålesund area, total	23 146	26 893	28 662	3748	1768	5516	23.8
Norway							14.2

Table 3
Car-driver shares (%) on all trips and work trips made by people living in the Ålesund area (the municipalities of Ålesund and Sula) and in Norway. N for the Ålesund survey, all trips: 2001;719, 2005; 704, 2009; 1061, 2013/14; 2225.
Source: National Travel Survey (Hjorthol et al., 2014).

Car-driver shares	2001	2005	2009	2013/14
All trips				
Ålesund-area	54.0%	57.9%	48.2%	60.9%
Norway	52.5%	54.2%	51.5%	54.4%
Work trips				
Ålesund area	68.8%	63.2%	58.6%	69.2%
Norway	62.9%	65.4%	61.3%	61.2%

4.1.3. Changes in travel behaviour

According to theory, the sprawling land-use development described above is expected to result in higher car-driver shares and longer travels. Data from the National Travel Survey show that the share of trips completed as car drivers in the Ålesund area increased from 2001 to 2013/14, with a stronger increase for all trips than for work trips (see Table 3). Compared with figures for Norway, Ålesund has had a stronger growth in shares of trips done as car drivers. There are surprisingly large variations from year to year, making us suspect uncertainties in the results, especially for 2009.

When analysing commuting statistics from SN, we find a 19% (1.7 km) increase in the average commuting distance from 2001 to 2017 for people living in the Ålesund area (see Table 4). This is a strong increase when compared to the average for all commutes in Norway (0.5 km, 3.6% increase). The increase in commuting distance was strongest on commutes done by those living in the extended city centre and weakest among those living in the outer urban area. One explanation for this could be the strong growth in the number of workplaces in the extended Moa area and the outer urban area, if more people living in the extended city centre now work at workplaces in those areas.

Analyses of commuting distances to workplaces located in the Ålesund area show a far smaller increase in average commuting distance in the period 2001–2015 (0.1 km, 0.5% increase; see Table 5). This is lower than that in Norway in the same period. The average commuting distance to jobs located in the extended city centre area was reduced in the period, while there was a strong growth in commuting distance to jobs located in the outer urban area. This could indicate that workplaces attracting employees from the larger city region have relocated away from the city centre to other areas. The difference in changes in commuting distances when focussing on the location of jobs and on where inhabitants live probably indicates that more people living in the Ålesund area commute to workplaces located outside our study area than did before.

4.1.4. Traffic volumes and congestion levels

Knowing the development as described above, it comes as no surprise that there has been a steady traffic growth in the area. Focussing on the road capacity expansion that is our case, traffic data from the NPRA (2016b, 2017) show a steady increase in total traffic volumes (on the new and the existing road) from about annual average daily traffic (AADT) 18 400 vehicles per day in 1998 (existing road only) to about 28 100 in 2016 (53% in total for both roads; see Fig. 3). In comparison, road passenger transport (vhkm) in Norway increased by 30% from 1998 to 2016 (SN, 2018b). Traffic on the existing road was reduced from about AADT 18 400 vehicles per day in 1998 to about 6700 in 2016 (64%), meaning that the local road has been relieved from through traffic, as planned. The 53% traffic growth in the corridor is considerably stronger than the 30% suggested in planning documents from Ålesund Municipality (1993, 2001). The planning documents did not specify which year they anticipated that traffic would have grown to 30% (about AADT 24 000). Fig. 3 shows that traffic had grown to this level around 2008, only six years after the new tunnel was opened, which we understand as sooner than expected.

We do not have data for congestion levels before the new road was built, but the interviewees and documents describe a situation with what was perceived as severe congestion problems (Ålesund Municipality, 1993). The congestion could last for more than an hour, especially when driving from the areas upstream of the tunnel toward the city centre in the morning rush. The interviewees stated that, in the first period after the road capacity expansion, congestion and delays were substantially reduced, almost down to zero, before the congestion slowly returned. Measures of congestion levels in 2012 show some delays in the section including the new tunnel in the morning rush hours going toward the city centre (average speed, 29–37 km/h compared with the 60–70 km/h speed

Table 4
Average commuting distances (km) for inhabitants living in different geographic zones in the Ålesund area (one way).
Source: Statistics Norway (2016).

Area	2001	2008	2015	Changes 2001–2008	Changes 2008–2015	Changes 2001–2015	Change (%) 2001–2015
Extended city centre area	8.1	10.2	11.0	2.1	0.8	2.9	35.1
Extended Moa area	7.9	8.7	9.3	0.8	0.5	1.3	16.5
Outer urban area	11.0	11.3	12.0	0.3	0.7	1.1	9.6
Ålesund area total	9.3	10.3	11.0	1.0	0.7	1.7	19.0
Norway	14.6	15.5	15.2	0.9	–0.3	0.5	3.6

Table 5
Average commuting distances (km) for employees to jobs located in different geographic zones (one way).
Source: Statistics Norway (2016).

Area	2001	2008	2015	Changes 2001–2008	Changes 2008–2015	Changes 2001–2015	Change (%) 2001–2015
Extended city centre area	15.0	14.0	14.2	−1.1	0.2	−0.9	−5.7
Extended Moa area	12.9	12.9	13.4	0.0	0.5	0.5	3.6
Outer urban area	10.2	11.4	12.1	1.3	0.6	1.9	18.6
Ålesund area total	13.3	12.9	13.3	−0.3	0.4	0.1	0.5
Norway	14.6	15.5	15.2	0.9	−0.3	0.5	3.6

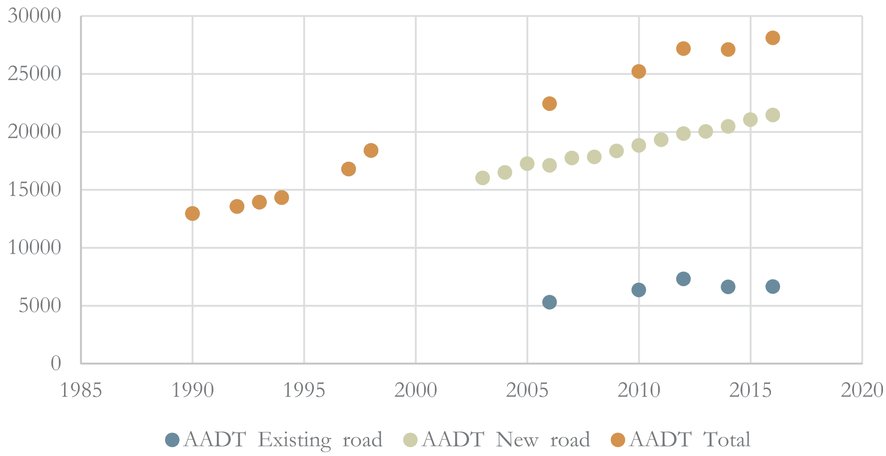


Fig. 3. Annual average daily traffic (AADT) in the existing road, the new road, and in total for both roads. All available data are presented in the figure. The new tunnel was opened in 2002.
Source: Norwegian Public Roads Administration (2016b, 2017).

limit) and in the Moa area (Levin, 2012 for the NPRA). The most severe delays are found closer to the city centre and in the city centre itself. The respondents were mixed in terms of whether this development was anticipated, but they seemed to agree that the congestion returned faster than expected.

4.1.5. Current situation and plans

The current traffic situation is understood as congested, and planning is underway to expand the road capacity with additionally two lanes (NPRA, 2013a). Goals listed in the planning document include, among other things, reducing the share of trips done as car drivers and keeping congestion levels down. The document states that a congestion-free future transport system cannot be expected. The indirect land-use effects discussed in this article are not mentioned in the preliminary impact assessment (NPRA, 2013a). In their 2017 municipal plan, the planning authorities in Ålesund focus on steering future land-use development in directions intended to stop the traffic growth, shift more of the transport to other modes than the private car and increase public transport competitiveness (Ålesund Municipality, 2017). The interviewees reported that it is hard to find ways of solving this, due to the sprawled land-use structure.

4.2. The Oslo case

4.2.1. Case description

The case in Oslo is an expansion of the main road connecting Oslo with its hinterland in south-east and south-eastern parts of Norway, as well as Sweden and Europe (E6). The road between Sweden and Norway was expanded and improved over a longer time. The last parts, crossing the borders of Oslo municipality, were between Klemetsrud and Assurtjern (7 km; construction period, 2002–2004) and between Assurtjern and Vinterbro (5.5 km; construction period, 2006–2009), see Fig. 4. The road was expanded from two to four/five lanes and upgraded with two-level interchanges. The main arguments for expanding the road capacity can be summarised as: To reduce congestion levels, which were predicted to worsen due to steadily increasing traffic volumes; to improve traffic safety; relieve a parallel road from through traffic; and improve the road connection to Sweden (NPRA, 1998).

The impact assessment calculated with a 30% traffic growth from 2003 to 2025 and assumed specifically that the capacity expansion would not cause induced traffic of significance (NPRA, 1998:102). An analysis by NPRA (2009) concerning further development of the transport system after the road capacity expansions were completed, suggested an 8% growth in inhabitants and a negative growth in number of work places in the Follo area from 2003 to 2015. The impact assessment found that the road capacity expansion would reduce congestion, and predicted significant travel time savings, even though it warned that there would probably

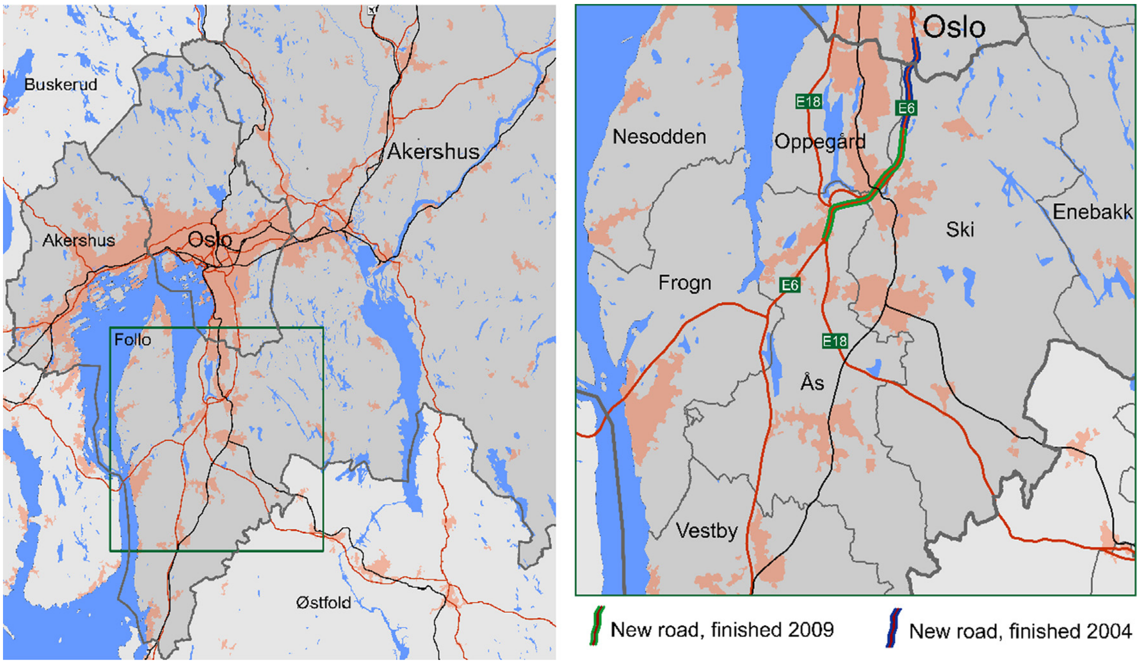


Fig. 4. Oslo case. The left image shows the location of the Follo area in Akershus, while the right image shows municipalities in the Follo area and the location of the road capacity expansions.

still be some delays in the morning rush hours (NPRA, 1998).

When analysing land-use development and changes in travel behaviour, we focus on development in the Follo area (about 125 000 inhabitants), since this area is located upstream of the road capacity expansion and is expected to have benefitted the most from increased accessibility due to the road capacity expansion (see Fig. 4). We study the development in four municipalities in Follo, located at different distances from Oslo city centre. Oppegård is the neighbour municipality, and that closest to Oslo (centre located 15 km from Oslo's city centre), followed by Ski (30 km from Oslo), Ås (40 km from Oslo) and Vestby (43 km from Oslo). We also compare development in the Follo area with development in Akershus County, to which Follo belongs, and in Norway.

4.2.2. Land-use development, planning and policies

When analysing land-use development in the Follo area in the period 2002–2016, we find a strong (21.9%) population growth (see Table 6). The growth is weaker than in Akershus (24.6%) and stronger than in Norway (15.2%). The relative population growth was strongest in the municipalities located furthest from Oslo (Ås and Vestby). We understand this as a sprawling tendency, since a higher percentage of inhabitants in the Follo area lives in areas further from the main city centre in the 'after' than did in the 'before' situation.

The number of new housing units is highest in the two most peripheral municipalities, and the shares of new housing built as flats in apartment buildings decreases with the distance from Oslo (see Table 7).

There has also been a strong growth in the number of workplaces (24.8%) in Follo in the period 2002–2016, which is higher than that in Akershus (18.5%) and throughout Norway (14.2%; see Table 8). Vestby, located furthest from Oslo, had the strongest growth, and almost a doubling of number of jobs.

In sum, these figures draw a picture of strong growth in population and jobs in the Follo area after the road capacity expansions,

Table 6
Population within geographic zones.
Source: Statistics Norway (2017b). The Follo area includes all municipalities in Follo.

Area	2002	2009	2016	Changes 2002–2009	Changes 2009–2016	Changes 2002–2016	Changes (%) 2002–2016
Oppegård	23 152	24 612	26 792	1460	2180	3640	15.7
Ski	25 763	27 699	30 261	1936	2562	4498	17.5
Ås	14 037	15 863	18 992	1826	3129	4955	35.3
Vestby	12 515	14 095	16 732	1580	2637	4217	33.7
Follo area	**113 171**	**123 986**	**137 965**	**10 815**	**13 979**	**24 794**	**21.9**
Akershus	**477 325**	**527 625**	**594 533**	**50 300**	**66 908**	**117 208**	**24.6**
Oslo	512 589	575 475	658 390	62 886	82 915	145 801	28.4
Norway	**4 524 066**	**4 799 248**	**5 213 913**	**275 182**	**414 665**	**689 847**	**15.2**

Table 7
Number of dwellings built in four Follo municipalities in the period 2007–2017, and percentages built as low-density development (detached houses, row-houses, etc.) and high-density development (apartment buildings). Dwellings designated for the elderly, students and so on are excluded. Data from Statistics Norway (2018a). Data only go back to 2007.

Municipality	Number of new dwellings 2007–2017	Share as detached houses and rowhouses (%)	Share in apartment buildings (%)
Oppegård	1350	35.0	65.0
Ski	1258	44.9	55.1
Ås	1702	58.5	41.5
Vestby	1746	63.1	36.9

Table 8
Number of employees at workplaces located within geographic zones.
Source: Statistics Norway (2017a).

Area	2002	2009	2016	Changes 2002–2009	Changes 2009–2016	Changes 2002–2016	Change (%) 2002–2016
Oppegård	9018	9135	8729	117	–406	–289	–3.2
Ski	10 881	13 610	14 235	2730	624	3354	30.8
Ås	6714	7374	8488	660	1115	1774	26.4
Vestby	3619	5056	6743	1437	1687	3124	86.3
Follo area	**39 475**	**45 515**	**49 278**	**6040**	**3763**	**9803**	**24.8**
Akershus	**210 240**	**246 331**	**249 116**	**36 091**	**2785**	**38 876**	**18.5**
Oslo	421 521	436 359	454 006	14 839	17 646	32 485	7.7
Norway	**2 256 948**	**2 514 597**	**2 576 578**	**257 649**	**61 981**	**319 629**	**14.2**

with a stronger growth in the most peripheral parts of the region, and housing development in the outer parts taking place mainly as low-density development (detached houses and rowhouses).

The causal relations between the road capacity expansions and the land-use development are also evident in this case. The main planning documents foresee growth in the number of inhabitants (but not jobs) in the Follo area and increased congestion if the road is not expanded; however, they do not mention the traffic situation as restricting this growth (Oslo Municipality and Akershus County, 1997; NPRA, 1998, 2009). The planning documents reveal a strong awareness of the potential for induced traffic following from the capacity expansion, and they are clear in their recommendations for steering land-use development to areas well served by public transport, especially by railway, to delimit traffic-inducing effects of the road capacity expansion. Still, the impact assessment is specific in stating that land-use development will not be affected by the capacity expansions (NPRA, 1998:102). The municipal master plans state a willingness to steer more of the development toward areas well served by public transport, but they also clarify that they will keep large, car-based development areas in their plans (Oppegård Municipality, 1994; Ås Municipality, 1995; Ski Municipality, 1995).

Interviewees at planning authorities in Oppegård and Ski, located closest to Oslo, claim that the road capacity expansion has not affected land-use planning and development in their municipalities much. They have experienced a high pressure on housing development for a long time, including before the road capacity expansion. They have been restrictive with respect to how much housing they have allowed built because physical and social infrastructure needs to be provided accordingly, among other reasons. Developments has mainly been allowed in and close to already built-up areas and centres with good rail services, often as densification and transformation, and more than before as flats in apartment buildings. An example showing that the road capacity expansion *has* affected land-use development is that Ski defined a large area for workplace development close to the expanded E6, which would not have been established if the road had not been expanded.

The restrictive land-use policy is followed even more strictly today (Oppegård Municipality, 2011, 2016; Ski Municipality, 2011), in accordance with the regional land-use and transport plan (Akershus County and Oslo Municipality, 2015) and developers' demands. Rail services to Oppegård and Ski will substantially improve in a few years, as a new line opens, and developers buy land and properties close to main railway stations since it is believed that these areas will become more attractive and valuable. The municipalities hope the improved rail accessibility will also attract more office- workplaces to their centres.

Planning authority interviewees in Ås and Vestby, located further out in the urban structure, reported a strong relationship between the road capacity expansion and land-use development and policies in their municipalities. A previous summer-cottage area located far from the centre and the railway station in Ås has grown to become the second most populous housing-area in the municipality. According to one interviewee, the road capacity expansion was a necessary condition and strong contributing cause of this. The interviewee in Vestby explained that municipal politicians saw the improved road accessibility as an opportunity for growth and development, and the municipality bought large tracts of land in areas close to the main roads. These areas were clarified for development, awaiting developers and businesses. This was a success, as reflected in the strong growth in the number of workplaces in the municipality, mainly related to logistics and regional retail.

In Ås and Vestby alike, the strong population growth is explained by the high housing and property prices in Oslo, causing especially young families to look for other options, as well as the municipalities' land-use policies. They have facilitated a range of different options with respect to housing development in their municipal plans, often based on proposals from landowners and

Table 9
Shares of trips taken as car drivers (%) of all trips and work trips starting or ending in the Follo area, Akershus in total, Oslo and Norway. N for Follo, all trips – 2001: 1420, 2005: 1253, 2009: 2078, 2013/14: 4525.
Source: National Travel Survey (Hjorthol et al., 2014).

Car-driver shares	2001	2005	2009	2013/14
All trips				
Follo area	58.3%	53.5%	52.5%	54.1%
Akershus total	57.7%	58.0%	57.5%	57.8%
Oslo	37.0%	33.6%	28.1%	29.4%
Norway total	52.5%	54.2%	51.5%	54.4%
Work trips				
Follo area	59.7%	61.0%	62.5%	59.2%
Akershus total	65.2%	69.7%	63.5%	63.1%
Oslo	44.1%	40.4%	32.8%	30.4%
Norway total	62.9%	65.4%	61.3%	61.2%

developers (Ås Municipality, 2017; Vestby Municipality, 2016). As a result, housing has largely been developed as detached houses and rowhouses, often on new land, and not within walking distance of the main railway stations. Both municipalities now aim at shifts in land-use policies, steering more of the growth toward areas in and close to their centres with railway stations, where they plan for several thousand dwellings, mainly as apartment buildings. Vestby is currently in the process of removing several planned housing areas on new land from their municipal plan. Both municipalities consider that the municipal plans in progress will be quite different from the current municipal plans (Ås Municipality, 2017; Vestby Municipality, 2017). The main explanations for these shifts are clear steering signals in the regional plan and demand from developers, who now are almost exclusively interested in developing central areas close to rail stations. Ås and Vestby alike expect that improved rail accessibility will enhance their attractiveness, and they hope to attract more workplaces.

4.2.3. Changes in modal splits and commuting distances

We have seen that there has been strong growth in the numbers of inhabitants and workplaces in the Follo area, especially in the outer areas, and that municipalities have had different policies and practices when it comes to steering land-use development. Hence, it is a bit surprising when data from the National Travel Survey show a decrease in the share of all trips completed as car drivers by people living in the Follo area, from 58.3% in 2001 to 54.1% in 2013/14 (see Table 9). In comparison, the situation was stable in Akershus in the same period, while there was an increase in Norway. The shares of work trips starting or ending in the Follo area carried out as car drivers were stable in the period, as they were in Norway, while the car shares were somewhat reduced in Akershus. The 2013/14 survey had high enough numbers of respondents (all trips) to allow for analyses at the municipal level. These figures show that Vestby had the highest car shares, with 65%, while Oppegård had the lowest, with 49%.

Commuting data show only a small increase in the average commuting distance for people living in the Follo area from 2001 to 2015 (0.3 km, 1.5%; see Table 10). This is lower than in Akershus and in Norway. We find increased commuting distances in the municipalities Ås, Oppegård and Ski, and reduction in Vestby. Commuting lengths increase with increasing distance from Oslo in the 'before' as well as in the 'after' situation.

When analysing commuting distances to workplaces located in the Follo area, we found a strong increase in the period 2001–2015 (3.5 km, 23.1%; see Table 11). This is far stronger than in Akershus and Norway in the same period. The increase in commuting lengths is strongest in Vestby and weakest in Oppegård. Commuting lengths to jobs do not vary much between municipalities.

This leaves us with a somewhat confusing picture of how the land-use development in the Follo area has affected travel behaviour. One explanation for the reduction in shares of car drivers on all trips could be related to the congestion combined with strong improvements of the public transport services since 2001 (PROSAM, 2014). However, we would expect this to have the strongest effects on work trips, in which we do not find a significant reduction. Another explanation could be that land-use development in parts of the Follo area has contributed to densification in ways allowing for higher percentages of the local trips being done by modes

Table 10
Average commuting distances (km) for inhabitants living in different geographic zones in the Oslo area (one way).
Source: Statistics Norway (2016).

Area	2001	2008	2015	Changes 2001–2008	Changes 2008–2015	Changes 2001–2015	Change (%) 2001–2015
Oppegård	15.4	15.7	16.3	0.4	0.6	0.9	6.1
Ski	17.7	17.7	18.4	–0.1	0.7	0.6	3.5
Ås	17.8	19.2	19.5	1.4	0.3	1.8	9.9
Vestby	28.6	26.4	26.8	–2.3	0.4	–1.8	–6.3
Follo area	**21.3**	**21.3**	**21.7**	**0.0**	**0.3**	**0.3**	**1.5**
Akershus	**17.8**	**18.0**	**18.4**	**0.2**	**0.4**	**0.6**	**3.2**
Oslo	8.9	9.3	9.6	0.4	0.3	0.7	7.8
Norway	**14.6**	**15.5**	**15.2**	**0.9**	**–0.3**	**0.5**	**3.6**

Table 11
Average commuting distances (km) to jobs located in different geographic zones (one way).
Source: Statistics Norway (2016).

Area	2001	2008	2015	Changes 2001–2008	Changes 2008–2015	Changes 2001–2015	Change (%) 2001–2015
Oppegård	17.3	17.1	19.3	−0.2	2.2	1.9	11.2
Ski	15.9	17.4	20.2	1.5	2.8	4.2	26.7
Ås	15.9	16.4	19.0	0.6	2.6	3.1	19.8
Vestby	15.8	19.1	21.0	3.2	1.9	5.2	32.7
Follo area	**15.2**	**16.2**	**18.7**	**1.0**	**2.5**	**3.5**	**23.1**
Akershus	**18.4**	**18.3**	**18.8**	**−0.1**	**0.5**	**0.4**	**2.3**
Oslo	20.3	18.6	17.8	−1.7	−0.8	−2.5	−12.4
Norway	**14.6**	**15.5**	**15.2**	**0.9**	**−0.3**	**0.5**	**3.6**

other than the private car.

4.2.4. *Traffic volumes and congestion levels*

Returning to the road capacity expansion that is our case, and analysing data from the NPRA, we find that total traffic volumes on the expanded and relieved roads (E6 and E18) increased from about AADT 52 300 in 2001, before the first phase of the construction works started, to about 68 000 vehicles per day in 2015 (30%; see Fig. 5). Total traffic volumes were stable in 1999–2003, while they increased by 9% in the period from 2003 (just before the first part of the road project was completed) to 2009 (just before completion of the last part) and 19% in 2009–2015 (after completion of the last part). This growth is stronger than the 30% growth in the period 2003–2025 as predicted in the impact assessment. Traffic on the E18, meant to be relieved from traffic, was reduced from AADT 23 900 in 2001 to 17 300 in 2015 (by 28%), while traffic on the expanded road increased from AADT 28 400 in 2001 to 50 561 in 2015 (by 78%). The total traffic growth in Norway was 22% in the same period (SN, 2018b).

Focussing on congestion levels, speed measuring done for the NPRA on a route starting south of the outermost part of the road-expansion project and ending in Oslo city centre, via E6 and E18, shows that the average speeds on the two roads were about the same or lower in rush hours in 2013 (the last available measurement) compared with 2003 (just before completion of the first part of the road capacity expansion; PROSAM, 2015; see Fig. 6). The average speed in afternoon rush hours increased after completion of the first part of the expansion on E6 and E18 and started to decline shortly after. The data show no increase in average speed after completion of the last part of the expansion. We see the lack of congestion relief on the expanded road as a result of the growth in traffic volumes. The relieved road was reorganised with public transport lanes, lower speed limits and so on, which could partly explain the lack of congestion relief here. We hence have a situation with more traffic congestion in 2013 than in 2003, since there are more cars on the road in the congested periods in 2013, with the same delays as in 2003. We understand this as less congestion relief than anticipated in the ex-ante analyses.

The interviewees at the NPRA agreed that the congestion level in rush hours had not improved, but they claimed that delays were substantially reduced at other times of the day. We do not have data to test whether this is the case.

4.2.5. *Current situation and plans*

The current congestion situation is understood as problematic. NPRA have plans underway to expand road capacity in the same corridor, closer to the city centre, to reduce congestion, delays for commercial traffic and local pollution (NPRA, 2016a, 2016b).

All four municipalities now see a shift in land use planning and policies. They aim at facilitating for land-use development in and close to their centres, where the main railway stations are located, and they are more restrictive with respect to low-density development on new land farther from the centres. This is a response to the 2015 regional plan and increased interest from private actors in developing areas close to the railway stations, as the rail connection toward Oslo will substantially improve in the coming few years.

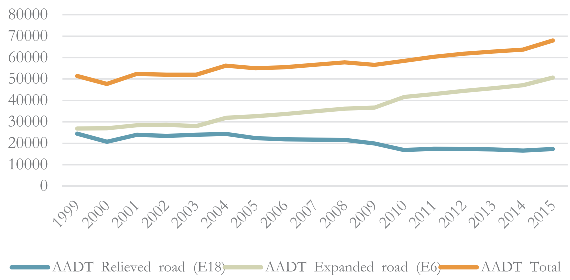
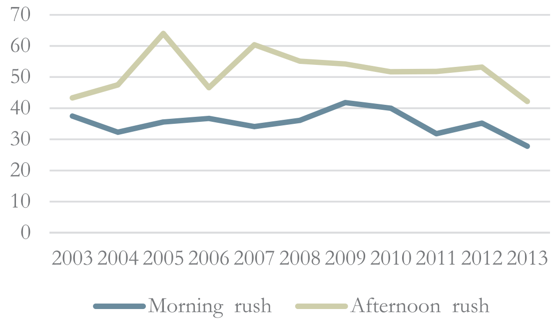


Fig. 5. Annual average daily traffic (AADT) on the expanded road (E6), on the relieved road (E18), and in total for both roads. Source: Norwegian Public Roads Administration (NPRA, 2015, 2018a, 2018b; PROSAM 2005a, 2005b).



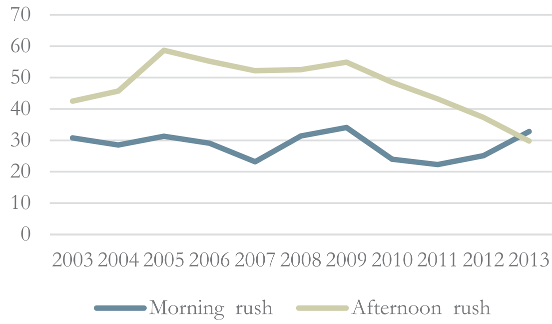


Fig. 6. Average speed (km/h) in 2003–2013, in rush hour directions in morning and afternoon rush, on the expanded road (E6; left) and relieved road (E18; right). Based on data from PROSAM (2015).

5. Case comparison and conclusions

One aim of this study was investigating whether and how the mechanisms described in Section 2 act out in different contexts, in the present research, a small and a large city. Leaning on the overview of the main findings from the case study, summarised in Table 12, we compare the two cases and conclude by answering the research question posed in Section 1.

5.1. Effects of road capacity expansions

In both cases, we found a strong growth in population and jobs in the areas getting improved accessibility due to the road capacity expansions, and the relative growth was stronger in the outer parts of the areas investigated. Much of the new housing has been built as low-density detached housing, and in Follo, the share of new housing built this way and on new land increased with the distance to the main city. In both cases we understand the overall development as sprawl, since higher percentages of jobs and inhabitants are

Table 12
Summary of the main findings in the two cases.

Indicator	Oslo case	Ålesund case	Norway
Land-use development, population, 2002–2016	Strong population growth (21.9%), the growth is stronger and more car-based with increasing distance from the core city	Strongest population growth in the outer urban areas (24.7%), lower in the extended city centre area (12.8%); most of the growth as low-density development and on new land	–
Land-use development, work-places, 2002–2016	Strong growth in number of jobs (24.8%), relatively stronger in outer parts of the urban region	Strongest growth in jobs in the extended Moa area (46.6%) and outer urban area (36.2%), less in extended city centre area (5,1%)	–
Land-use planning and policy in the period	Varying in Follo municipalities. All allowed for strong population growth. Less strict steering of land-use development in more peripheral municipalities, with the result that the share of housing allowed built as low-density development on new land increases with distance from Oslo	Allowed for strong growth in populations and jobs located outside extended city centre area, weak steering, much left to developer and landowners	–
Current land-use planning and policy	Stricter land-use policy, steering growth toward areas close to centres with good rail connections, discussing road projects to reduce congestion	Trying to steer growth towards densification in already built areas, plans for further expanding our case road underway	
Car-driver share, all trips	Decreased from 58.3% (2001) to 54.1% (2013/14) in the Follo area	Increased from 54% (2001) to 60.9% (2013/14)	Increased from 52.5% (2001) to 54.4% (2013/14)
Car-driver shares, work trips	Stable: 59.7% (2001) and 59.2% (2013/14)	Stable: 68.8% (2001) and 69.2% (2013/14)	Decreased from 62.9% (2001) to 61.2% (2013/14)
Commuting distances, to/from home (2001–2015)	Increased by 1.5 km, 0.3%	Increased by 1.7 km, 19%	Increased by 3.6 km, 0.5%
Commuting distance to/from job (2001–2015)	Increased by 3.5 km, 23.1%	Increased by 0.1 km, 0.5%	Increased by 3.6 km, 0.5%
Traffic volumes, total for expanded road and parallel relieved road	30% increase (2001–2015)	53% increase (1998–2016)	22% increase (2001–2015) 30% increase (1998–2016)
Congestion levels in rush hours	Same in 2013 as in 2003	Congestion has returned but is probably less severe	–

located in peripheral areas in the 'after' than in the 'before' situation. The growth in population and jobs seem to have been stronger than anticipated in ex-ante plans and analyses.

The causal relationship between the road capacity expansion and land-use development was clear in both cases. It was most evident in Ålesund, where congestions in the 'before' situation clearly hampered development in the outer parts of the urban area. In Oslo, this relationship was weaker in the municipalities located closest to Oslo, who had experienced high development pressure in the 'before situation', and stronger in the more peripheral municipalities, who experienced higher pressure after completion of the capacity expansion.

These findings are in accordance with theory, as discussed in Section 2, and they are expected to result in longer trips and higher car-driver shares. We found increasing commuting distances within the areas studied in both cases. Car-driver shares (all trips) increased in Ålesund, which is in accordance with theory. In the Follo area, they decreased, and our best explanation for this was that the land-use development contributed to increased densities, allowing more of the local trips to involve other modes than the private car. Following from that, no or only short-term reductions in congestion levels in rush hours were observed. Traffic growth was stronger and congestion relief weaker than anticipated in ex-ante plans and analyses in both cases. In both cases, the intended traffic relief on parallel roads was achieved.

In both cases, the NPRA has plans underway to expand road capacity in the corridors investigated, to reduce congestion.

In conclusion, our first research question *'How have urban road capacity expansions affected land-use development, consequently affecting traffic volumes and congestion levels, in the cases?'* can be answered as follows: We found that the road capacity expansion was a contributing cause for a more sprawled and car-dependent land-use development than what would otherwise have occurred, as well as longer commutes, in both the smaller and the larger city. This contributed to stronger traffic growth in the road corridors than would otherwise have occurred, and no or only short-term reductions in congestion levels in rush hours.

5.2. How the land-use effects were affected by land-use and policy

The cases clearly demonstrate that land-use planning and policy influence the land-use effects of road capacity expansions. This is most evident when comparing municipalities located close to the main city in the Oslo case with those located furthest away. Planning authorities in the municipalities closest to Oslo steered land-use in ways that resulted in higher shares of new housing units built as apartment-buildings, close to centres and rail stations. In the more peripheral municipalities, authorities left more to landowners and developers. As a result, much of the new housing was built on new land and as detached houses and rowhouses. This leaves the municipalities closest to Oslo with a less transport-demanding and car-dependent spatial structure than the more peripheral municipalities have. In the Ålesund case, the planning authorities allowed housing and workplace development in outer parts of the urban area, and much of the housing was built as low-density housing, also on new land. A different strategy would have left them with a less transport-demanding and car-dependent city. In both cases, planning authorities and politicians now want to stop the sprawl and steer the development of housing and workplaces toward centres and areas with excellent public transport services. In Follo, this is a response to strong signals from developers related to upcoming improved accessibility by rail, and it is in accordance with the regional plan.

On this basis, our second research question '*How have land-use planning and policy affected the land-use effects of road capacity expansions?'* can be answered as follow: The traffic-inducing land-use effects were weaker where municipalities took a strong position and steered toward high-density land-use development in areas close to centres with excellent public transport accessibility, and stronger where municipalities allowed landowners and developers to build on new land, with lower densities, in areas with poor public transport accessibility.

5.3. How road capacity expansions affect the chances to stop traffic growth in urban areas

Based on our analyses, we find in both cases that the road capacity expansions were a necessary condition for the traffic-inducing land-use development, which in turn contributed to traffic growth and returned congestion. Thus, the answer to our third question '*How do road capacity expansions affect the potential to stop traffic growth in urban areas?'* would be that these findings add to the body of studies concluding that expanding urban road capacity is more of a part of the problem than the solution for cities striving to achieve more sustainable urban mobility and more adequate policy responses are needed, and that this also is valid for smaller cities.

6. Discussion

To succeed in making cities more liveable, climate-friendly and efficient, planners and decision makers need to do things differently than before. A *reframing* of the problems as well as of the strategies and means considered to solve the problem is required (Owens and Cowell, 2002, Tennøy, 2010), as is a deep understanding of the complex interrelations between the development of land-use, transport systems, travel behaviour and traffic volumes.

The aim of this research has been to contribute to this understanding by empirically documenting effects of road capacity expansions on land-use, travel behaviour and traffic volume in more disaggregated, context-related and nuanced ways than seen in previous studies, and by including how land-use planning and policy influence the traffic-inducing effects. Findings were held up against ex-ante expectations at the time the projects were planned.

In the smaller as well as the larger city, main findings were that the road capacity expansions were contributing causes to land-use sprawl, increased commuting lengths and strong traffic growth, resulting in no or only short-time congestion relief. Consequently, new road capacity expansions aimed at reducing congestion levels are currently under planning or discussion. In both cases, traffic growth was stronger than described in planning documents, and the congestion relief weaker. Ex-ante analyses seem not to have included the indirect land-use mechanisms discussed here, and this could be one explanation why there are discrepancies between ex-ante expectations and the actual development.

A question arising from these findings is how *current* planning processes relate to this knowledge. Document studies and interviews reveal that ongoing planning processes in the two case cities suggest only alternatives including road capacity expansions in plans aimed at reducing congestion and traffic-related local environmental problems, and that the indirect land-use mechanisms discussed here are not taken into consideration (NPRA, 2013a, 2013b, 2016a). This indicates that planners and authorities still have the understanding that expanding road capacity is a way of solving the problems, and that they disregard the land-use effects of road capacity expansions.

Another interesting question is the contrafactual one: What could or would have happened if the road capacity was not expanded in the two cases? One answer could be that the land-use would have developed as documented anyhow, followed by car usage increasing to the same volumes as we see today, leading to intolerable congestion. An alternative understanding could be that congestion, combined with authorities steering land-use development in less car-dependent directions, while substantially improving public transport services, facilitating bicycling and walking and introducing fiscal and physical restrictions on car usage, could have shifted travel behaviour toward less car usage (as discussed, for instance, by Banister, 2011; Nicolaisen and Næss, 2015; Litman, 2018; Rode et al., 2017; Verma, 2018). The probability of the latter scenario is strengthened by the findings in the Oslo case, where all four municipalities currently experience that upcoming improved rail accessibility make central areas close to railway stations highly attractive for developers. If the rail accessibility had been improved before or instead of the road accessibility, as several authorities argued in the planning process (NPRA, 1999), land-use in the Follo area could have developed in less transport demanding and car dependent ways, resulting in less traffic and congestion, and contributing to achieving the zero-growth objective. Seen in the light of goals related to reducing car-dependency, congestion and GHG-emissions from transport in countries and cities across the globe (European Environment Agency, 2018; UN Habitat, 2013), this is an interesting possibility that could be considered as an alternative in future planning processes.

Reframing understandings of how traffic and congestion problems could be solved and changing current practices is, however, not an easy task. It requires that new knowledge and ideas are understood and applied in complex planning processes, with multiple actors from different levels and sectors, who often have different goals (Bryson et al., 2015; Flyvbjerg, 1998; Hanssen et al., 2013; Tennøy, 2010; Zellner and Campbell, 2015). By presenting empirical findings in disaggregated, context-related and nuanced ways, our aim has been to contribute with relevant and understandable knowledge, that might contribute to the necessary reframing and change of planning practice and policy if prioritised societal goals are to be achieved.

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Appendix A. Interviewees

Interviewee	Case
Planner, Ålesund Municipality	Ålesund
Senior Architect, Ålesund Municipality	Ålesund
Planner, Ålesund Municipality	Ålesund
Planner, Sula Municipality	Ålesund
Retired Planner, Norwegian Public Roads Administration	Ålesund
Planner, Norwegian Public Roads Administration	Ålesund
Developer, Ålesund	Ålesund
Head of Planning Department, Oppegård Municipality	Oslo
Head of Planning Department, Ås Municipality	Oslo
Senior Planner, Ski Municipality	Oslo
Retired Planner, Vestby Municipality	Oslo
Director, Road Directory, Norwegian Public Roads Administration	Oslo
Director, Planning Department Road Directory, Norwegian Public Roads Administration	Oslo

Appendix B. Interview guide

The ‘before’ situation

– What was the situation at the time when the road was planned with respect to the road itself, traffic, land-use, planning, etc.?
– What were the main motivations for expanding the road capacity?

– What were the expectations for congestion reduction, traffic growth, land-use development, etc., resulting from the capacity expansion?
– Were other options than expanding the road considered to solve the problems experienced?

Development after the road capacity expansion

– How did the traffic and congestion change after completion of the road? (On the new and old roads)
– How has land use developed after the road capacity expansion? How do you explain this development?

Current planning and plans

– What are the main land-use strategies in the current plans and plans in progress, at the municipal and regional levels? What are the motivations for this?
– Are there any current plans or plans in progress for road constructions? What are the motivations for this?

Appendix C. Supplementary material

Supplementary data to this article can be found online at https://doi.org/10.1016/j.trd.2019.01.024.

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