Available online at www.sciencedirect.com

ScienceDirect

Transportation Research Procedia 19 (2016) 4 – 17

Transportation Research Procedia

www.elsevier.com/locate/procedia

International Scientific Conference on Mobility and Transport Transforming Urban Mobility, mobil.TUM 2016, 6-7 June 2016, Munich, Germany

Experiences with capacity reductions on urban main roads – rethinking allocation of urban road capacity?

Aud Tennøy *, Paal B. Wangsness, Jørgen Aarhaug and Fredrik Alexander Gregersen

Institute of Transport Economics, Gaustadalléen 21, 0361 Oslo, Norway

Abstract

This paper presents results from a study concerning effects and consequences of a temporary (one year) capacity reduction on an urban main road tunnel in Oslo, Norway. The main findings are that reduction of the road capacity from in total four to two lanes in the Smestad tunnel, carrying about 50 000 vehicles per workday, caused few or no effects or consequences. Three months after the capacity reduction was implemented, traffic volumes were about the same as before, there are only small increases in delays, and the road users (commuters and freight traffic) have not made significant adaptions.

Peer-review under responsibility of the organizing committee of mobil.TUM 2016.

Keywords: Reduction of urban road capacity; traffic volumes, delays, behavioural adaption

1. Introduction

Ten tunnels on the urban main-road system in Oslo will undergo substantial rehabilitation in the period 2015 – 2020. These are dual tunnels, carrying 20 – 75 000 cars a day. The works require closing down the tunnels, or parts of them, and hence significantly reducing the road capacity for shorter or longer periods of time. We see this as natural experiments, offering great opportunities for researching effects and consequences of capacity reduction on urban highways, for the transport systems as well as for the users.

* Corresponding author. Tel.: +47-900-38-220; fax: +47 22 60 92 00.
E-mail address: ate@toi.no

Peer-review under responsibility of the organizing committee of mobil.TUM 2016.
doi:10.1016/j.trpro.2016.12.063

This is highly relevant knowledge, for two main reasons. One is that increasing parts of urban road systems are built as tunnels, and tunnels are maintenance intensive. Hence, tunnel works and tunnel capacity reductions will occur more frequently in the future. Knowledge concerning effects and consequences of such incidents could help improving transport authorities' mitigating measures and information to the public in such situations. Another reason is that many countries and cities strive to achieve more sustainable urban mobility, with shifts from private cars to more environmentally friendly modes of transport. In Norway, the Parliament's climate agreement, the National Transport Plan as well as many county- and municipal plans have stated objectives of zero-growth in traffic volumes or reductions in total traffic volumes in the cities (Ministry of Transport 2013). Such objectives relate to reduction of greenhouse gas emissions, but also to cleaner air, more efficient urban transport systems, more liveable and attractive cities, more lively city centres, etc. An evident measure if one aims at shifts to more sustainable transport modes, is to reallocate road space from cars to other modes. Such initiatives are however, often met by arguments that reduced road capacity will cause congestions, chaos and less people visiting the city centre, and cause problems for people in their everyday lives and for commercial traffic.

In their much-referred study, Cairns et al. (2002:21) analysed 70 case studies of roadspace reallocation from eleven countries, and found that *"well-designed and well-implemented schemes to reallocate roadspace 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 main roads, where information about what is to happen has resulted in reduced traffic volumes, and hence far less congestion and chaos than expected. In 2009, the capacity on the main road (E18) passing Oslo city center was reduced from three to two lanes in each direction, due to construction works. The traffic on the link (normally carrying about 85 000 vehicles per workday) was reduced by 13 percent that day, and by five percent on analytically selected routes in the road system in the city (Eriksen and Torp 2009). There were no significant increases in delays in the transport system. In Trondheim, one of two lanes in each direction on a main road leading into the city center were reallocated from general traffic to dedicated bus lanes in 2008. There was some increase in delays the first few days, before the situation stabilized (Asplan Viak 2008). Public transport speed increased by 16 percent in the morning rush and 25 percent in the afternoon rush. After six months, traffic on the link was reduced by 5 000 cars a day, and after two years by 7 000 cars a day. Traffic increased by 500 and 800 vehicles on the most relevant alternative routes.

Hence, it may seem that the expectations of congestions and problems if road capacity is reduced often is exaggerated. This could be an advantage in situations where capacity needs to be temporarily reduced, if it contributes to reduce traffic and congestions. On the other hand, it may be disadvantageous if the authorities consider reallocation of roadspace from general traffic to more sustainable transport modes, and base their assessments on faulty assumptions. By researching effects and consequences of capacity reductions on urban main-road tunnels in Oslo, our aim is to contribute to strengthening the knowledge base, allowing planners and political decision-makers in cities across the world to make plans and decisions contributing positively to their defined objectives, and to reduce negative impacts of future temporary capacity reductions.

2. Results from a pilot study: Effects and consequences of capacity reduction in the Smestad tunnel

Institute of Transport Economics, together with national and local transport authorities, public transport authorities, planning authorities, private transport actors and others, initiated a large-scale research project aiming is to investigate effects and consequences of a number of major changes that will occur in the transport system in Oslo the next five years, including the tunnel capacity reductions. The research is financed by the co-operating actors and the Norwegian Research Council. In a pre-project, we investigated effects and consequences for the transport systems and for users of the transport systems of the capacity reduction of the first tunnel that was rehabilitated (the Smestad tunnel) and of a case where a subway line was replaced by bus due to construction works on the subway line (Tennøy et al. 2015). These studies are understood as pilot-studies. The aims were to develop and test research design and methods for data collection and analyzes, to produce knowledge to be used in subsequent, similar cases, and to investigate the effects and consequences of these specific changes in the transport systems. In this paper, we report results from the first phases of the tunnel capacity reduction case. We have continued, and will continue, to collect data until the situation is back to normal. The full analysis of the Smestad tunnel case will be reported then. We choose to present the results from the first phase now, in order to share results from the pilot studies, invite other researchers to comment on our methods, analyzes and findings, and maybe to get in contact with other researchers doing similar research.

The Smestad tunnel is a dual tunnel with two lanes in each direction, carrying an annual average workday traffic of about 50 000 vehicles. The tunnel is 500 meters long, and it is part of an important ring road, distributing traffic in Oslo, often termed Ring 3, see figure 1.

Figure 1: Map showing Ring 3 and the alternative routes Ring 2 and E18 Bjørvika. Map based on Esri.

The traffic is similar in both directions, also in rush-hours. In the evening Monday 1st of June 2015, two of the four lanes in the tunnel were closed due to construction works, and the capacity of the tunnel was halved. The speed limits were reduced from 70 to 50 kilometers per hour, and temporary bus lanes were introduced. Other minor mitigation measures were also implemented. Before the Norwegian Public Roads Authorities (NPRA) started the construction works, they ran a large information campaign, warning travelers that the capacity reduction probably would cause heavy congestion and delays, and encouraged users of the road to find other ways of traveling in rush-hours.

3. Approach and research questions

Assuming that people aim at reducing travel time, improving travel comfort or reducing direct expenses related to travelling, the relative and absolute qualities of the transport-systems (for cars, public transport, bicycling, walking) matter for people's travel behavior. 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 one mode of transport become better, compared to conditions for other modes, the shares of this mode will increase (Cairns et al. 2002, Downs 1962, 2004, Goodwin 1996, Mogridge 1997, Noland and Lem 2002, SACTRA 1994). Travelers respond to changes in the transport systems in different ways. Cairns et al. (2002:19) describe a number of behavioral responses: They may change route, timing of their journey, transport mode, travel frequency, what is done on the trip, destination, and driving style.

In our study of effects and consequences of the traffic capacity reduction in the Smestad tunnel, we focused on rush-hour traffic. Leaning on previous research, we defined the following research questions for the Smestad case:

- How did the capacity reduction in the Smestad tunnel affect the traffic on this link (traffic volumes, speeds, congestion levels)?
- How did commuters and freight transport adapt to the capacity changes (changes of route, mode, trip-timing and travel frequency)?
- Which effects and consequences were experienced in other parts of the transport system (alternative roads, public transport system, bicycle network)?
- What were the effects and consequences of their adaptions or non-adaptions for commuters and freight transport?
- Did the information measures reach the public and the users of the road, and how did road users respond to the information?

4. Research design and methods for data collection

The research was designed as a case study. We collected data in three pre-defined time-periods. These were two weeks just before the tunnel works started (weeks 19 and 21, 2015), the two weeks right after the tunnel works started (weeks 23 and 24, 2015), and two weeks in the autumn (weeks 38 and 39, 2015) when we assumed the traffic situation would have stabilized. We also collected historical data from the same time-periods in 2014, where such data were available. The selected time-periods are understood as quite stable when it comes to traffic volumes, compared to other periods, when holidays and weather (snow) affect the situation. They are also within the bicycle season. Data from the different time-periods were compared in analyzes aimed at revealing whether the capacity reduction in the Smestad tunnel had led to any empirically observable effects and consequences.

Methods and sources for collecting data for analyzes presented in this paper were:

- Traffic volumes and speeds from a number of traffic counters operated by national and municipal transport authorities, some permanent and some temporarily installed for this study
- Bicycle volumes from a number of traffic counters operated by national and municipal transport authorities, some permanent and some temporarily installed for this study
- Average speeds on links, from the service reisetider.no, operated by the national road authorities
- Passenger figures and changes in delays for relevant bus routes, obtained by the public transport authorities
- Surveys amongst employees in 10 companies located in areas we assumed would be affected by the capacity reduction in the Smestad tunnel before the capacity reduction (May 2015, 247 respondents) and in the stable underway-situation (September 2015, 313 respondents) (conducted by Institute of Transport Economics)
- Data from the fleet management systems of a large freight operator
- Interviews with four truck-drivers right after the capacity reduction was implemented (June 2015) and in the stable underway-situation (September 2015) (conducted by Institute of Transport Economics)

For all these kinds of data, there are uncertainties, deficits, natural variations, and missing data. The most problematic difficulties were that important data collection points for road traffic were out of order in some or all data collection periods. Hence, we have deficient data series for some data collection points, and for others we have been forced to use the 'next-best' data collection point. The technology for obtaining bicycle data is under development, leading to some difficulties, such as counting devices being out of order. We have not been able to specify the bus passenger data to the preferred level. Surveys and interviews will always be influenced by the subjective understandings of the respondents. Further, the number of respondents were lower than they ideally should have been in the surveys, as well as with respect to interviews with lorry drivers.

We have done what we could to improve the data quality, by critically scrutinizing and discussing traffic data, analyzes and findings with the specialists at the transport authorities, and check data quality in situations where deviations made us suspect serious faults. As a result, some data sets were discarded, and we chose nearby traffic counters instead. In other cases, faults were corrected or misunderstandings clarified. All together, we believe the data quality is satisfactory. We have also compensated data uncertainty by investigating important issues with the help of different methods and (triangulation - as listed above), and by keeping our analyzes on a relatively rough level. Hence, we are quite certain that our main findings are sound. Through the pilot-study, we learnt a lot which has contributed to improve the data collection and analyzes in the main project. We hope that our experiences in the pilot-study may be useful for other researchers doing similar research.

5. Findings

5.1. Effects on traffic volumes on the link where capacity was reduced

Figure 2 shows average traffic volumes in rush-hours morning (7.00 – 9.00) and afternoon (15.00 – 17.00) on the link affected by the capacity reduction in the three analytically selected data collection periods in 2015, as well as data from similar periods in 2014. The capacity reduction was implemented Monday evening in week 23. Data is collected in the Tåsen tunnel, 3,8 kilometers east of the Smestad tunnel, since the traffic counters directly related to the Smestad tunnel was out of order due to the tunnel works. Data from this counting point is missing for week 24 2015, due to technical problems.

The figure shows that traffic volumes are quite stable. Week 23 differs from the other periods, by having significantly less traffic. Compared to weeks 20 and 21 in 2014, the traffic is reduced by 2 500 vehicles, or 25 percent, in the morning rush, while the reduction in the afternoon rush is 2 100 vehicles, or 23 percent. Compared to the weeks just before the capacity reduction was implemented, traffic was down 2 100 vehicles, or 22 percent, in the morning rush, and 1500 vehicles, or 17 percent in the afternoon rush. The weeks before the capacity reduction in the Smestad tunnel (weeks 19 and 21), one eastward lane on the link close to the Smestad tunnel was closed due to construction works. Hence, traffic volumes were somewhat lower in these weeks than they normally would be. We found the same patterns, but with less reduction in week 23, when we analyzed another data collection point further from the Smestad tunnel, but in the same system. Hence, we believe the effects on traffic volumes would have been stronger if measured in the Smestad tunnel, rather than in the Tåsen tunnel. In the stable underway-situation (weeks 38 and 39, when the tunnel capacity was still reduced), traffic was back to the same levels as before the tunnel capacity was reduced.

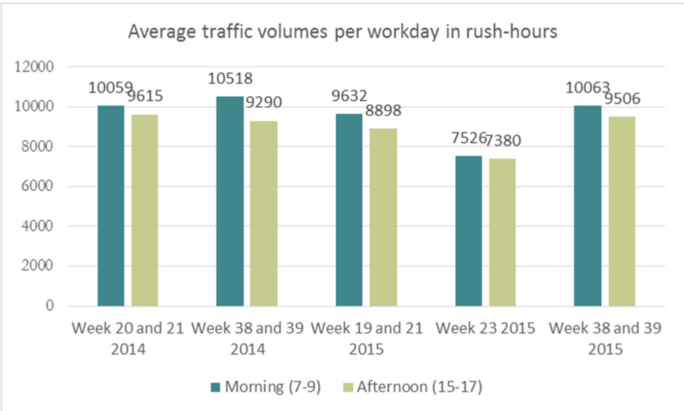

Figure 2: Average traffic volumes in morning (7.00 – 9.00) and afternoon (15.00 – 17.00) rush-hours on workdays, total for both directions, number of vehicles, measured in the Tåsen tunnel. The capacity reduction was implemented Monday evening week 23 2015[i].

We also analyzed data from a point located ca 20 kilometers south of Oslo city center, which we assumed would not be directly affected by the capacity reduction in the Smestad tunnel. We found no reduction in traffic volumes in this point. Hence, our understanding is that the traffic reduction measured in the Tåsen tunnel are caused by people adjusting to information about expected congestions, delays and chaos, by avoiding this part of Ring 3. This behavioral adaption is in accordance with findings in other similar studies (Cairns et al. 1998, 2002).

It is also interesting to have a look at how traffic volumes developed the first week after the capacity reduction (week 23, 2015). Figure 3 shows traffic volumes in morning rush-hours (7.00 – 9.00) in weeks 21 and 23.

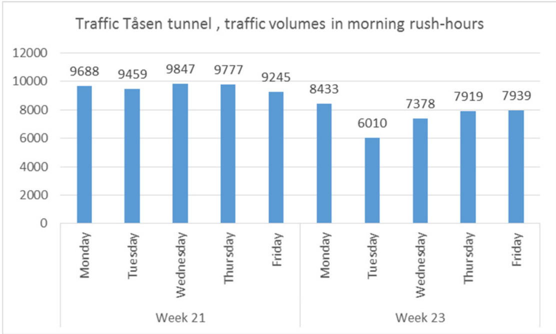

Figure 3: Average traffic volumes in the Tåsen tunnel each weekday in weeks 21 and 23 2015, morning rush-hours (7.00 – 9.00), total for both directions, number of vehicles. The capacity reduction was implemented Monday evening week 23 2015.

Traffic volumes are quite stable through week 21, and somewhat reduced Monday in week 23, and significantly reduced on Tuesday (the first morning-rush with reduced capacity). When comparing traffic volumes in morning rush-hours (7.00 – 9.00) Tuesdays in weeks 21 and 23, we find a reduction of about 3 500 vehicles or 37 percent. Traffic volumes start rising already on Wednesday (an increase of 1 360 vehicles, or 23 percent, from Tuesday to Wednesday), after media had reported that the expected congestions had not occurred. This illustrates that traffic volumes are quite flexible.

We have traffic data from the Smestad tunnel for weeks 38 and 39, 2015. Measured at the western tunnel mouth, before the ramps take off, the average traffic per rush-hour per direction (traffic on one lane plus the ramp) is about 2 000 vehicles per hour. Maximum load measured in one hour was 2 450 vehicles. We do not have good data for traffic on the ramps, but manual sample counts indicate that traffic on the ramps are between 600 and 700 vehicles per rush-hour. This means that traffic volumes on each lane in the Smestad tunnel normally are between 1 300 and 1 400 vehicles per hour, which is within what is assumed as allowing a free-flow state at speed limits of 50 kilometers per hour.

5.2. Effects on speed and delays on the link where capacity was reduced

We analyzed how the capacity reduction, and behavioral changes related to this, affected speed and delays on the affected link. As reported in many similar cases (Cairns et al. 1998), the expectations (and the signals from NPRA) were severe delays and heavy congestion. The press geared up to cover the incident, but ended up reporting that traffic was smooth, see figure 4.

Fig. 4: The photo at right shows some of the journalists gathered to cover congestions and chaos expected to occur when the capacity reduction in the Smestad tunnel was implemented on the 2nd June 2015 (photo: Norwegian Public Roads Administration). The photo at left shows the situation in the area in the morning rush (photo: Aud Tennøy). There was not much congestion and chaos to report.

Knowing the effects on traffic volumes (as illustrated in figure 2), it is no surprise that traffic was almost free-flowing the first days after the capacity reduction. It is more interesting to analyze the speeds and delays in the stable underway-situation, when traffic is back to previous levels, but with reduced road capacity. Figure 5 shows average speeds in morning (7.00 – 9.00) and afternoon (15.00 – 17.00) rush-hours on the link Ullevål – Lysaker, separated on east-west direction, for selected weeks in 2014 and 2015. This is a nine-kilometer stretch of Ring 3, and includes the Smestad tunnel. Data are based on registrations of individual cars in two registration points, and average speeds and delays are calculated based on this.

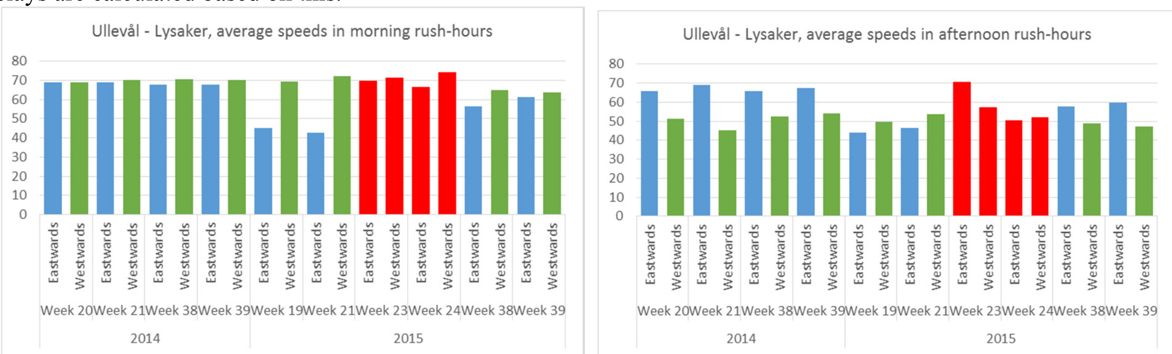

Figure 5: Average speed (kilometres per hour) in morning (7.00 – 9.00) and afternoon (15.00 – 17.00) rush-hours on the link Ullevål - Lysaker, including the Smestad tunnel, in selected weeks in 2014 and 2015. Blue columns represent eastward traffic, green columns westward traffic. Red columns represent traffic the first two weeks after the capacity was reduced. Data from Reisetider.no.

The figure at left, illustrating average speeds in morning rush-hours, shows a state of free-flowing traffic in 2014, and for westwards traffic in weeks 19 and 21, 2015 (speed limits are 70 kilometers per hour). Eastward traffic has delays and reduced speed in weeks 19 and 21, 2015 due to the previously mentioned construction works closing one eastward lane. In weeks 23 and 24, traffic is almost free-flowing. In weeks 38 and 39, speeds in morning rush-hours are somewhat lower than in the before-situation. Calculating the extra time it takes to drive the nine kilometer stretch eastwards in the 2015 situation (average speed 57 kilometers per hour) compared to the 2014 situation (average speed 70 kilometers per hour), we find an increase in average delay on the stretch of about 1,8 minutes. For westward traffic, extra delays are about 0,6 minutes. Doing the same exercise for afternoon rush, illustrated in the figure at right, we find that average extra delay is about 1,2 and 0,8 minutes. Speed limits are 50 kilometers per hour in and close to the tunnel in the situation with capacity reduction, and 70 kilometers per hour on rest of the stretch. We also found increased variability in speeds and delays, meaning an increased risk of experiencing congestion and extra delays when driving on this part of Ring 3. Hence, based on traffic data, we found that although traffic volumes seem to be the same as before, the capacity reduction has on average not caused severe extra delays or congestion on the link, but the risk of being delayed has increased.

In the survey in the stable underway-situation (September 2015), we asked if the commuters used longer or shorter time on their travel to work now, compared with the situation before the tunnel works started. 59 percent of all car-drivers (N=120) and 83 percent of the public transport users (N=125) answered that there were no changes. Six percent of the car drivers and two percent of the public transport users answered ‘shorter’, while 32 percent of the car-drivers and six percent of the public transport users answered ‘longer’. On average, those car drivers reporting that they used longer time answered that they used 11 minutes more now than before. Public transport users reporting that they used longer time reported averagely 10 minutes extra. We suspect that the discrepancy between results from traffic data and survey is partly due to us posing the question in a way that may have caused respondents to answer it with respect to the maximum delay they have experienced. We also suspect respondents to overrate how much extra delays and negative effects the tunnel works caused. We are looking forward to comparing the answers in the stable underway-situation (May 2016) with the answers to how much time respondents experience they save after the capacity is back to normal.

5.3. Changes of route choice, mode choice, trip-timing and travel frequency

We expected people to adjust their travel behavior in ways causing reduced traffic on the link both in the first days after the capacity reduction was implemented, and in the stable underway-situation. Hence, we sought to measure these behavioral changes, by measuring the transport and by asking commuters and lorry-drivers.

We analyzed if we could measure any rerouting and consequences for other parts of the road traffic system. We collected data from traffic counters along the alternative main roads, Ring 2 and E18 Bjørvika, as well as smaller roads assumed to be relevant alternative routes, see figure 1. We found no significant increases in traffic levels on Ring 2, E18 Bjørvika or the smaller roads, neither for the weeks right after the capacity reduction was implemented (week 23 and 24 2015) nor for the stable underway-situation (weeks 38 and 39 2015). See figure 6 for figures from E18 Bjørvika and Ring 2.

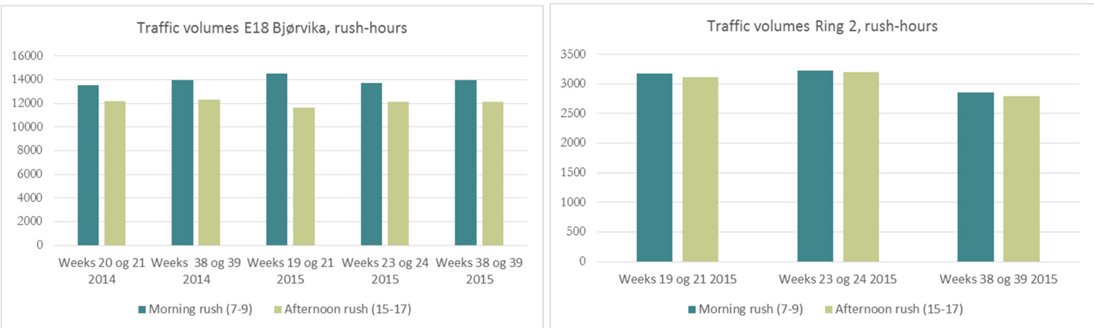

Figure 6: Average traffic volumes per workday in rush-hours in the morning (7.00 – 9.00) and the afternoon (15.00 – 17.00), total for both directions, number of vehicles. The capacity reduction in the Smestad tunnel was implemented week 23, 2015.

Hence, traffic data show no sign of rerouting. In the survey in the stable underway-situation (week 38 and 39 2015), six percent of respondents reporting that they normally drive Ring 3 on their way to work reported that they had changed routes due to the tunnel works. In retrospect, we have understood that we should have asked this question with respect to their previous journey to work. As it was asked in this survey, respondents may have ticked this alternative if they had chosen another route only one or a few times. We have changed the way we ask this question in the questionnaires for the subsequent tunnel-cases.

Further, we aimed at finding out whether people had adjusted to the tunnel works by changing modes of transport. In the surveys (in May, before the tunnel works started, and in September, when the situation had stabilized), we asked employees at workplaces we assumed would be most affected by the tunnel works how they had travelled to work the previous day. We found no significant changes with respect to modal shares. This in accordance with the findings that traffic volumes are about the same in May and September.

We also analyzed passenger data for relevant bus lines from the public transport authorities (Ruter). These are data for embarking passengers, for whole lines and whole weeks, and hence not as specific as we wanted (which would be rush-hour traffic on the most relevant parts of the lines), see figure 7.

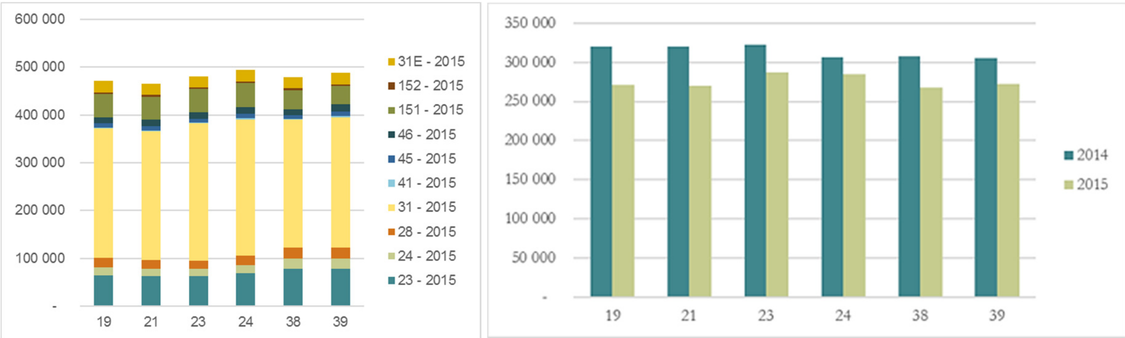

Figure 7: Figure at left, number of passengers per week on ten relevant bus lines (whole lines) in relevant weeks in 2015 (19 and 21 before the tunnel works started, weeks 23 and 24 right after the tunnel works started and road traffic was reduced, and weeks 38 and 39 understood as stable underway-situation and where road traffic volumes were back to normal). Figure at right, number of passenger per week on bus line 31, serving the relevant area and with most passengers in Oslo, the similar weeks in 2014 and 2015 (whole line).

The figure at left shows that the number of passengers are higher in weeks 23 and 24 than in the previous weeks (up from about 471 000 and 465 000 passengers in week 19 and 21 to 481 000 and 494 000 passengers in weeks 23 and 24). This may indicate that some of those not driving to work due to the tunnel works in weeks 23 and 24 shifted to bus instead. There are, however, also more passengers in weeks 38 and 39 (480 000 and 488 000 passengers), when road traffic was back to normal (as shown in figure 2). Analyzing the data more in detail, we found that the higher figures in weeks 38 and 39 are mainly (but not only) due to more passengers on line 23. The public transport authorities changed to longer buses with more capacity on this line in august 2015, which may have contributed to more passengers.

The figure at right shows the number of passengers on line 31, which serves the relevant area and which is the heaviest bus line in Oslo, in relevant weeks in 2015 and the similar weeks in 2014 (for comparison with respect to seasonal variations). When merging two and two weeks, we find 5,6 percent more passengers in weeks 23 and 24 than in weeks 19 and 21. In absolute figures, this equals about 2 500 more passengers per weekday. In weeks 38 and 39, passenger numbers are about the same as in weeks 19 and 21 (before the tunnel works started). We do not find a similar pattern in 2014. Together, this indicates that some of those not driving along this part of Ring 3 in weeks 23 and 24 went to work by bus instead of by car these weeks. In the main project, we will gather more specific data (rush-hours, specific areas or stops), enabling us to draw stronger conclusions with respect to shifts between car and public transport.

We also gathered data for bicycle traffic in the relevant weeks. We have data from 11 traffic counters spread across the bicycle-network in Oslo. There is no reason to believe that those who previously drove on Ring 3 chose to travel along this road if they went by bicycle, but rather that they would spread across the networks. Compared to week 21, bicycle-traffic increased by 13 percent in week 23 and 33 percent in week 24. In weeks 38 and 39, bicycle traffic is about the same as in week 21. These figures indicate that some of those who chose not to drive along Ring 3 the first weeks after the tunnel works started, shifted to bike.

We tried to analyze if there was changes in trip-timing (increased traffic in the hours before and after the rush-hours), and found no such changes. We did, however, not have very good data for these analyzes. In the survey, 29 percent of those normally driving along Ring 3 on their way to work, reported that they had changed their trip-timing. Again, the question was asked in a way that may have caused respondents to tick this alternative if they had chosen to start their trip earlier or later than normal only one or a few times. Hence, we cannot say if there have been any significant changes in trip-timing.

Concerning travel frequency, we asked respondents in the surveys how often they had home-office. We found no significant changes from the before to the underway-situation. We are uncertain how well this describes changes in travel frequency.

Interviews with lorry-drivers are in accordance with these findings. They report that the capacity reduction in the Smestad tunnel has not driven them to make detours or do any other adaptions to the situation.

5.4. Effects and consequences for commuters and freight transport

An important issue was to investigate which effects and consequences the capacity reduction in the Smestad tunnel had for commuters (all modes) and for freight transport. In the survey to commuters in the stable underway-situation (September 2015), 68 percent of all respondents and 60 percent of those driving along Ring 3 on their way to work, reported that there were no changes in the quality of their travel to work, see figure 8.

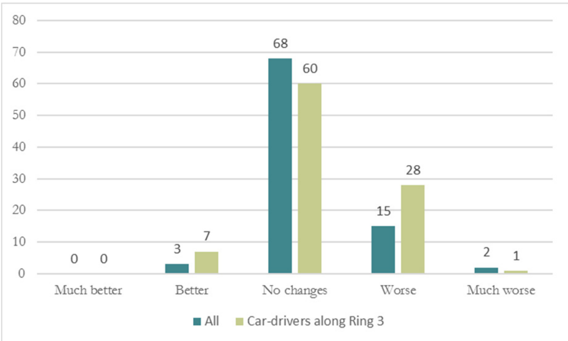

Figure 8: Commuters' answers to the question 'Have you experienced that your travel to work has become better or worse due to the works in the Smestad tunnel?' N=313 for all, N=72 for car-drivers along Ring 3.

15 percent of all, and 28 percent of the car-drivers along Ring 3, reported that the situation had become worse, while 3 percent of all and 7 percent of the car drivers reported that it had become better. Almost nobody (1-2 percent) reported that it had become much worse. When asked how the travel to work had worsened, the most frequent answers were increased travel time (13 percent), more congestion (10 percent) and more crowded public transport (7 percent). They could choose multiple alternatives.

Further, we asked if the tunnel works and effects of this (such as increased delays) had caused any consequences for the household, concretized to changes in responsibilities, routines, etc. concerning shopping, collect and deliver children, etc. About five percent reported any such changes.

Hence, we conclude that the capacity reduction in the Smestad tunnel had only small effects and consequences, for a rather small group of commuters.

Also, analyzes of the freight transport data showed no effects or consequences, measured as delivery-precision. We have about 6800 observations of freight trips for the entire Oslo-area for the three two-week periods in this case study. In the areas where any effects of the capacity reduction in the Smestad tunnel were expected to be seen, i.e. in the western parts of Oslo and the neighboring municipalities Asker and Bærum, we have about 1400 observations. On average throughout a year, about 91 percent of the deliveries are made within the pre-set time windows, neither too late, nor too early. The average annual share of deliveries outside of time windows is about 9 percent, with normal weeks varying between 7 percent and 11 percent. From figure 9 we see that the delivery precision was within the normal range, with 8 and 7 percent respectively, in the weeks just before the capacity reduction and in the assumed stabilized situation, whereas the weeks right after had somewhat higher precision than normal, with 5,7 percent. The main reasons for deliveries outside of the time windows also vary between the case study weeks. In the weeks just before and right after, the most common reason for not delivering within the time window, was because of delays from previous deliveries. In the weeks assumed stabilized the most common reason was too early arrival.

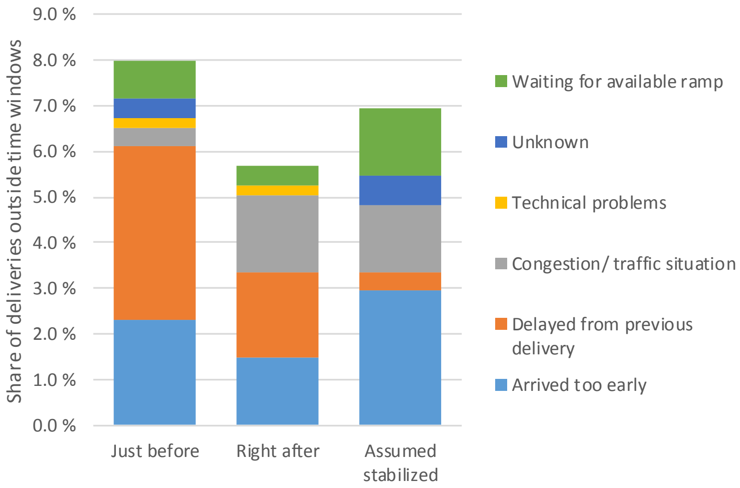

Figure 9: Delivery precision in the western parts of Oslo and in neighbouring municipalities Bærum and Asker. N=1444.

We thus cannot observe any effects or consequences on delivery precision related to the capacity reduction in the Smestad tunnel. The interviews with the lorry drivers confirm that the situation is more or less business as usual. Some of them experienced less congestion in the weeks right after, and in the weeks assumed stabilized they could not tell if there were any differences in congestion levels. The capacity reduction in the tunnel had not led to any changes in their freight transport process, and thus had no effect on cost efficiency.

5.5. Effects of information campaign

The national road authorities, responsible for Ring 3 and the tunnel works, launched a large-scale information campaign the weeks before the tunnel works started. They placed ads in the big newspapers, gave interviews in newspaper, on radio and TV, informed households through letters, held information meetings at large workplaces, informed via signs along Ring 3, etc.

In the survey in the stable underway-situation (weeks 38 and 39, 2015), we asked if respondents felt they had received sufficient information about the tunnel works before they started, and what were the most important sources of information, see answers in figure 10.

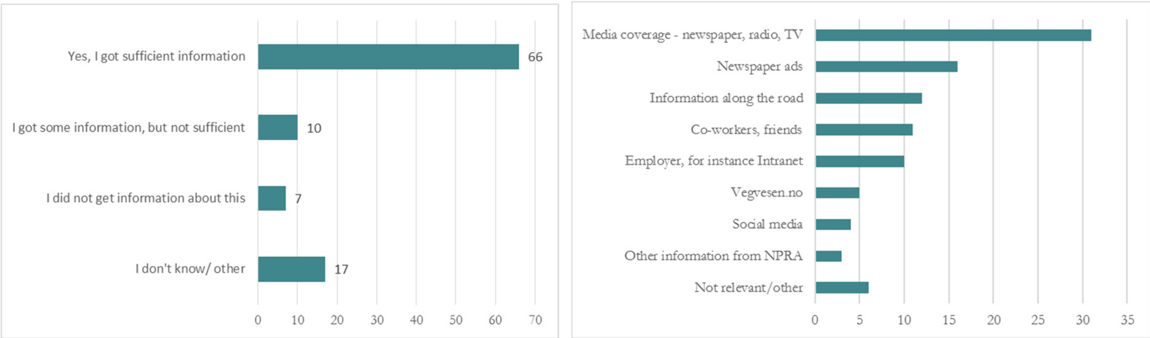

Figure 10: Commuters' answers to the question 'Did you get sufficient information before the tunnel works in the Smestad tunnel started?' at left, and 'Which were the most important sources of information? You can choose up to three answers'' at right. N=313 for both. Percent.

66 percent of the respondents answered that they had received sufficient information before the tunnel works started, and ten percent that they had received some, but not sufficient information. Only seven percent answered that they did not get information about this. The most important sources of information were coverage in newspapers, radio and TV (31 percent), newspaper ads (16 percent), information along the road (12 percent), co-workers and friends (11 percent) and employer (10 percent). These answers, together with the significant traffic reductions the first days after the capacity reduction was implemented, show that the information campaign was successful and had effect.

6. Discussions and conclusion

In the pilot study of effects and consequences, for the transport systems and their users, of a capacity reduction from four to two lanes in the Smestad tunnel, we have analyzed different kinds of data in order to answer the research questions defined in section 3.

We found that the information campaign launched before the capacity reduction in the Smestad tunnel was successful. The first days and week after the capacity reduction, traffic on this part of Ring 3 was significantly reduced. Already the second day after the capacity reduction, traffic started to increase. In the stable underway-situation, three months later, traffic volumes are back at the same levels as before the capacity reduction. Since traffic was significantly reduced the first days, it is no surprise that there were no increases in delays or congestions. It may be more surprising that we find only small increases in delays in the stable underway situation, when capacity is halved in the tunnel and traffic is back to previous levels.

Concerning behavioral adaption, we found that about 25 percent of those normally driving on Ring 3 in rush-hours found other ways to get to work the first week, and about 37 percent the first day. We found increased patronage on bus-lines serving the area assumed most affected by the capacity reduction the two weeks just after the capacity reduction, and significant increases in bicycle traffic across Oslo. We hence conclude that some of those not driving along Ring 3 the first days and weeks after the capacity reduction, chose to go to work by bus or bike instead of by car. We found no evidence of rerouting in our data, and these are robust findings. Neither did we find evidence of change of trip-timing or reduced travel frequency. Our data are, however, weak on these issues.

Some car- and public transport users reported in the survey that the capacity reduction had contributed to increased travel time on travels to work. We suspect that this is over-reported, due to the way the question was posed. Five percent of the respondents in the survey reported that the capacity reduction had caused changes in household routines and responsibilities.

Lorry-drivers reported in interviews that the capacity reduction had not caused extra delays for them, and they had not made any changes in their daily routines, neither in the situation just after the capacity reduction nor in the stable underway-situation. Analyses of delivery-precision data from a large freight-operator data confirm that the capacity reduction had not caused measurable changes in delivery precision.

The findings can be explained in several ways. Our main explanation so far is that the road capacity in the Smestad tunnel was not reduced to a level lower than the traffic volumes it carried in the before-situation, and which it still carries in the stable underway-situation. Traffic on each lane in rush-hours are normally between 1 300 and 1 400 vehicles per rush-hour, which is within what is understood as the capacity of one land with speed 50 kilometers per hour. Hence, the capacity reduction did not cause large enough extra delays to make people change their travel behavior. Further, the speed reduction from 70 to 50 kilometers per hour would normally increase the capacity of the road. Drivers might also have adopted a more efficient driving-style.

Before concluding, we would like to reflect on what the Smestad tunnel is a case of. As we see it, this is *not* a case of capacity being reduced below the traffic on the road, leading to behavioral changes. Rather, it is a case demonstrating that *expectations* of increased congestions led to behavioral changes, and that urban commuters *do* have alternatives to the private car. It is also a case of exaggerated expectations of congestion and chaos due to road capacity reductions. Hence, our findings are in accordance with theory and previous empirical findings in studies of similar cases (Cairns et al. 1998, 2002).

Our findings, together with previous research, raises questions concerning our understanding of effects and consequences for transport systems and their users if road capacity is reallocated to alternative uses, as well as our understandings of urban traffic, urban congestion, and how it could be regulated and handled. Hence, it raises questions about how we could and should think about allocation of urban road capacity in a sustainable urban mobility perspective. We know that the knowledge planners and decision-makers use when making plans often are not in accordance with research based state-of-the-art knowledge, for several reasons (Næss et al. 2013). We also know that whether planners use such knowledge strongly affects the goal achievement potential of the plans they produce (Tennøy 2010, 2012, Tennøy et al. 2016). We are confident that the main project will result in new and useful knowledge for urban planners, transport planners and other professionals aiming at transforming urban mobility in many cities in Norway and elsewhere. The findings from the pilot study have already been used as input in the preparations for the capacity reductions in the Granfoss tunnel (October 2015) and the Brynstunnel (February 2016) in Oslo.

Acknowledgements

We would like to thank the referees reviewing this paper for the TUM conference for insightful and useful comments that helped us improve the paper.

References

Asplan Viak (2008) Evaluation of public transport lanes in Trondheim. Asplan Viak, Oslo.

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

Cairns, S., Hass-Klau, C. and Goodwin, P., 1998. "Traffic impact of highway capacity reductions: assessments of the evidence". Landor publishing, London.

Downs, A., 1962. The law of peak-hour expressway congestion. Traffic Quarterly, Vol. 16, pp. 393-409.

Downs, A., 2004. Still stuck in traffic. Coping with peak-hour traffic congestion. Brookings institution press, Washington D.C.

Goodwin, P. (1996) Empirical Evidence on Induced Traffic. Transportation, Vo. 23, No. 1, pp. 35-54.

Ministry of Transport (2013) Meld. St. 26 (2012-2013). National transport plan 2014-2023.

Mogridge, M. J. H., 1997. The self-defeating nature of urban road capacity policy. A review of theories, disputes and available evidence. Transport Policy, 4 (1), 5-23

Næss, P., Hansson, L., Richardson, T. and Tennøy, A., 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, 14(4), 470-491.

Noland, R. B. & L. Lem, L. L., 2002. A Review of the Evidence for Induced Travel and Changes in Transportation and Environmental Policy in the US and the UK. Transportation Research D, Vol. 7, No. 1, Jan. 2002, pp. 1-26.

SACTRA, 1994. Trunk Roads and the generation of traffic. MSO, London.

Torp, A. and Eriksen, T. (2009) Traffic before and after capacity reduction in Bjørvika/ E18 Festningstunnelen. PROSAM, Oslo.

Tennøy, A., 2010. Why we fail to reduce urban road traffic volumes: Does it matter how planners frame the problem? Transport Policy 17 (2010) 216 – 233.
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 2012:01, Norwegian University of Life Sciences.
Tennøy, A., Hansson, L., Lissandrello, E. and Næss, P. (2015) 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, doi:10.1016/j.progress.2015.05.002.
Tennøy, A., Wangsness, P.B., Aarhaug, J., Gregersen, F.A. and Fearnley, N. (2015) Pilot studies: Before- and underway studies of the Østensjø subway line and the Smestad tunnel. TØI report 1455/2015.

[i] Rush-hour traffic vary from day to day. Weekly averages for rush-hour traffic varies from 8 898 to 10 518 vehicles. St.d. vary between 290 and 1 380 for the two week periods. There is no statistically significant change between the average rush-hour traffic before the capacity reduction, and during. However, the traffic in week 23 is significantly lower compared with the other periods.