Transport solutions to improve local air quality

A meta study of updated knowledge of strategies and measures to improve local air quality with focus on exhaust gases

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Photo: Knut Opeide, Statens vegvesen

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Content

1. Preface

This work was preformed by a working group under Nordisk Vejforum (NVF) in 2022 and 2023. NVF wants to contribute to the dissemination of the knowledge about local air quality. Therefore, this working group was established to collect relevant reports and other documents that sums up relevant knowledge about local air quality, with focus on cities in Nordic countries. The working group will release two reports. This report will handle pollution from exhaust gas, the other report will handle pollution from road wear. The working group includes staff from Statens vegvesen (Norway), Vegagerðin (Iceland), Trafikverket (Sweden), Edeva (Sweden), Reykjarvíkurborg (Iceland), Lunds Universitet (Sweden), VTI (Sweden), Trondheim kommune (Norway), Opplysningsrådet for veitrafikken (Norway), Heilbrigðiseftirlit Reykjavíkur (Iceland), Norges lastebileier forbund (Norway), Umhverfisstofnun (Iceland), and Trafikanalys (Sweden).

This report is written by:

- Michelle Benyamine Remahl, Trafikverket, Sweden
- Hans ten Berg, Trafikanalys, Sweden
- Karl Idar Gjerstad, Statens vegvesen, Norway (Project leader)
- Thorleif Foss, Norges Lastebileier-Forbund (NLF), Norway
- David Eskilsson, Edeva, Sweden
- Rikard Gaarder Knutsen, Opplysningsrådet for veitrafikken (OFV), Norway

2. Summary and main findings

This report is the result of some of the collaborations that took place in the NVF air quality group, with focus on transport policies and development that promotes flexible mobility which improve air quality in urban environments. Themes we cover is *Urban planning*, *Active mobility* primarily with focus on walking, cycling and public transports, *Environmental zones* and the *Future vehicle fleet* with focus on digitalisation, electrification and automatization. We have chosen to delimit the report from goods transport and only focus on passenger transport.

The work in this report has aimed to collect relevant, and most updated, knowledge of local air quality for the Nordic countries. This report has been delimited to transport policies for passenger's transport and development that promotes flexible mobility. Therefore, this work is mainly about strategies and mitigations that reduces emission of exhaust gases, and not emission from road wear. Some main findings from this work are summarized in the following bullet points.

- The traffic volume has been increasing the last decades in the Nordic countries, and the current prognosis shows that it will continue to increase the next decades.

- Despite higher traffic volume, the level of exhaust gas has been decreasing. Nevertheless, the level of NO_2 is still too high compared to the guidelines in many Nordic cities. There is also a need to reduce the emission of greenhouse gases to reduce global warming. Therefore, it is still important to develop Nordic cities to reduce all emission from traffic.

- Urban planning is a powerful tool for avoiding future local air pollution. It is a broad a complex field that includes both planning in and building infrastructure as well as policy. Urban planning to promote active mobility has double effect, as transport without emission replaces cars and because active mobility itself has a public health effect. Densification of cities, building infrastructure that reduces the need for passenger cars, promoting public transport, and parking restrictions are also strategies that have effect on local air quality. Thus, the effect of good urban planning is on long term, and it might be hard to quantify the effect. A key point is that the effect of urban planning is most successful when several of these strategies are carried through in a complete way together ("*The whole is greater than the sum of its part*").

- There are established environmental zones in many European cities. These are organized quite differently, and could to a large extend be adapted to any local need. Today, most of the zones are aimed for heavy vehicles, but environmental zones might as well be used for passenger cars. Model studies shows that environmental zones could certainly have a strong effect on the local air quality.

- The vehicle fleet is currently in the middle of a huge change where cleaning technology through the euro classes and introduction of electrical cars strongly reduces the emissions of harmful gases and CO_2 from tailpipes. This development is an opportunity to introduce efficient mitigations that was not that strong ten years ago. For instance, this is a fundamental condition to make any successful low emission zone. One should still be aware that the lower emission from tailpipes is only one of many challenges of traffic in urban areas. It does not affect emission from road wear, noise, or challenges of urban land use.

- Work to improve local air quality certainly meets several of UNs sustainable developments goals. The most obvious is goal 3 “Good health and well-being”, but also goal 11 “Sustainable cities and communities”, and goal 13 “Climate action” are relevant. In general actions to meet these goals are coincident, but some goal conflicts might occur.

3. Introduction

According to the National plan 2022-2033 from the Swedish Transport Administration, swedes travel 40 kilometers per day domestically, all means of transport and reasons in total. Just over three quarters is by car. The Swedish Transport Administration has recently compiled data mainly from the agency Transport Analysis, showing how distribution of transport in vehicle kilometres has changed from year 1990, Figure 1.

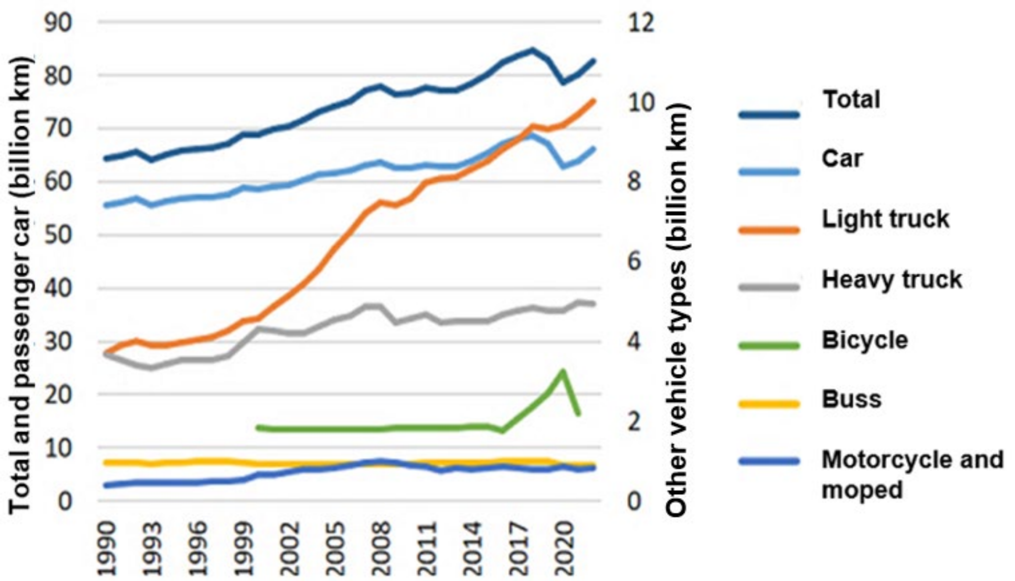

Figure 1: Distribution of transport in vehicle kilometers from year 1990 to 2022.

Calculations based on the Swedish Transport Administration's basic forecast show that transportation will increase by 10 percent per person and that car traffic will increase by approximately 30 percent from 2017 to 2040. The increase in traffic is expected to be greatest in the most densely populated regions.

In history, the situation of air quality has been shifting. Up to the 80s, the level of NO_2 was increasing due to more traffic. In the 90s, it was reduced due to the introduction of the three-way catalyst for petrol cars. But from year 2000 it increased again because of the increased share of diesel cars (this was mainly a problem in European countries). In most European countries, the level of NO_2 peaked between 2010 and 2015. Since then, the level of NO_2 is strongly reduced due to emission requirements in the following euro classes, especially Euro 6/VI. In Norway, the level of NO_2 has reduced by 50 percent from 2012 to 2023 (Figure 2) and in Sweden NOx has reduced by 47 percent during the parallel period[1].

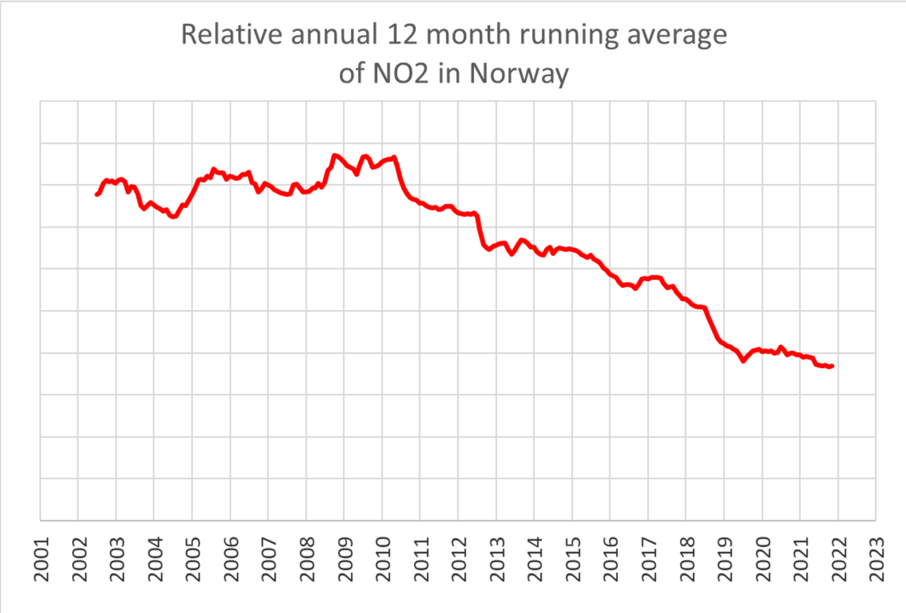

Figure 2: Relative rolling 12-month NO_2 level measured on 11 different monitoring station in Norway. There are no numbers on the y-axis as this is the average of different monitoring station and this average should not be compared to any limit values. This figure is included to show the trend of the NO_2 level over time. Data is from https://luftkvalitet.nilu.no/.

Emission of exhaust particles have decreased correspondingly. However, the emissions of wear particles have not been reduced in the same way. Lower emissions due to lower studded tire shares in the Scandinavian urban areas has been offset by higher emissions from increased traffic flows and heavier vehicle fleet.

Among the diseases that WHO counts as direct consequences of poor air is respiratory and cardiovascular diseases linked to birth, children's allergies, and dementia. A clear connection is presented between long-term and short-term exposure to local emissions and mortality [2]. Long-term exposure of traffic wear and tear and exhaust particles (PM2,5) and nitrogen dioxide (NO_2) caused 1,400 premature deaths in Sweden according to calculations in 2019[3].

4. Urban planning

Growing populations and car traffic in cities pose challenges to city planners in the form of increased congestion on roads and demand for parking, crowding in public transport and more car traffic, and may also affect overall safety and comfort in infrastructure for walking and cycling. Current

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[1] Trafikverket (2023). Trafikverkets miljörapport 2022. Publ. nr. TRV 2023/29370. Trafikverkets Miljörapport 2022 (diva-portal.org)

[2] Forsberg B. et al (2021). Bättre metoder att beskriva hälsovinster av minskad luftföroreningsexponering från vägtrafik. Publ.nr. 2021:25

[3] Gustafsson M. et al (2022). Quantification of population exposure to NO_2, PM2,5 and PM10 and estimated health impacts 2019. IVL No. B 2446.

Scandinavian transport planning models do not handle these factors and solutions currently appear distant as good data is largely lacking.

According to a report with the aim to test a model for strategic planning of sustainable urban transport in Scandinavia[4], results indicate that higher parking fees and more central location of new housing may be effective in reducing car traffic and increasing the mode shares of walking, cycling and public transport in Uppsala. Public costs for these policies are estimated to be about 25 percent lower than for the reference scenario. In contrast, increases in supply, lower charges, or concentration of the capacity to bus trunk lines with increased speeds have smaller effects on mode shares. Increased supply and lower charges are costly to the public purse, whereas the trunk line policy has somewhat lower costs. The central conclusion is that results appear to be plausible and the model useful to planners.

City centers should be planned with regard to environmental quality standards for outdoor air quality, and the goal should be that densification does not impair human health. Denser cities can result in and enable reduced car traffic as transportation with less environmental impact can be used more frequently. However, denser cities can also cause poorer ventilation in urban spaces so that levels of air pollutants that are harmful to health increase. Increasing urbanization also puts more people at risk of exposure.

4.1 Routine on air quality in planning buildings

In 2021 The Swedish Transport Administration published a routine to be used in the collaboration with the municipalities in their community planning[5]. The ambition is to work for the development of denser cities at the same time as the built-up area and traffic in urban areas are developed so that people are not exposed to health risks. Model studies, i.e. analyzes using simulation tools of how air quality changes and how people are exposed to air pollution, can be used to compare different plan proposals from an air quality point of view. Important parameters are road sections, drawing and design of tunnels, covers and screens, street space including width and distance between facades, street width, the traffic area, house height, estimate of the number of vehicles and proportion of heavy traffic. By intelligently ventilating closed street rooms, high levels of pollution can be reduced without concentrating them in other nearby areas. A varied structure of buildings, squares and parks are also good examples that can reduce pollution levels and exposure, as well as the width of the street rooms is important.

To reduce the levels of air pollution, vehicles with lower emissions and reduced traffic work on the roads are required. The increased electrification and the development of a cleaner vehicle fleet contribute to the reduction of emissions. At the same time, the EU is introducing progressively stricter emission requirements for air pollution for new vehicles, which also affects the total emissions positively. Direct measures that reduce road transport work are, for example, public transport lanes, driveway parking, planning and construction of local and regional cycle paths, coordinating freight transport and congestion taxes. Stage 1 and stage 2 measures, in relevance to the so called four-step principle[6], are, for example, targeted information and communication about

[4] Pydokke R., Norheim B., Fossheim Betanzo M. (2017). A Model for Strategic Planning of Sustainable Urban Transport in Scandinavia - A Case Study of Uppsala. CTS Working Paper 2017:7
[5] Swedish transport administration (2021). Luftkvalitet vid planering av bebyggelse. Rutinbeskrivning TDOK 2021:0086
[6] Fyrstegsprincipen - Bransch (trafikverket.se)

alternative modes of travel with public transport, travel-free meetings, carpooling and procurement requirements.

5. Mobility in urban environments

5.1 Health effects of active mobility

Active transport - walking and cycling - seems to be a solution to several of the great challenges of our time. This applies perhaps most of all in the field of transport. An increased proportion of walking and cycling increases the transfer from car use to footpaths and cycle paths, which leads to a reduction of greenhouse gases, air pollution and noise. At the same time, an increase in walking and cycling gives more space for gathering places, parks, and green areas in the cities as motoring takes up large areas. An increase in walking and cycling also combats one of the great challenges - sedentary lifestyle and low physical activity - which seriously threatens our health.

In fact, active transport is such a powerful factor that it creates greater positive health effects than the transport system produces in negative terms from air pollution, noise and lack of road safety combined. To know how big extent traffic-related air pollution, noise, active transport (walking and cycling) affects human health, the Swedish authority Transport analysis calculated health effects in terms of DALY on Swedish conditions. DALYs for a disease or health condition are the sum of the years of life lost to due to premature mortality (YLLs) and the years lived with a disability (YLDs) due to prevalent cases of the disease or health condition in a population. Today's active travel contributes to that approximately 73 600 lost function-adjusted life years can be avoided, which corresponds to what noise (about 41 000 DALYs), air quality (about 19 400 DALYs) and traffic fatalities (about 10 900 DALYs) have negative effects together (71 300 DALYs in total)[7].

Health gains are expected in a mitigation from a car driven society to a more walking and cycling friendly society. Socioeconomically there are huge benefits as well. A scenario of increased cycling when commuting to work in Greater Stockholm showed that a little over 111 000 short work journeys by car could be transferred to an average of 15 to 30-minute cycle trips, which could lead to health economic gains of several billion kroner per year. Walking and cycling form the base of the movement pyramid which can contribute even more to increased public health. This motivates major investments in the transport sector to create safe, secure, and attractive route environments for pedestrians and cyclists[8].

In other words, the transport sector already contributes to health, but has extraordinary opportunities to contribute even more through measures that stimulate access walking and cycling.

5.2 Learnings from the corona shutdown

In 2020, the global covid 19-pandemic broke out. The spread of infection led to several countries introducing varying degrees of lockdowns, which greatly affected mobility. Significantly more people stayed at home instead of commuting daily to their workplaces. The lockdown measures introduced by most European countries, led to significant reductions in emissions of air pollutants, particularly from road transport, aviation, and international shipping. All estimates show that NO_2 concentrations

[7] Transport analysis (2019). Mer hälsa för pengarna? Slutrapport i fördjupning av de transportpolitiska målen – hälsa och livsmiljö. Rapport 2019:15. Stockholm.

[8] The Swedish Transport Administration (2015). Om gång och cykling, hälsa och en hållbar utveckling. ISBN: 978-91-7467-816-1. Borlänge.

were considerably reduced across Europe in April 2020[9], independently of the meteorological conditions. The estimated relative reductions in NO_2 concentrations varied considerably within cities and across countries. The relative reductions were greatest where lockdown measures were more severe, i.e., in Spain, Italy and France, and closest to traffic, while reductions were lower in central-eastern Europe, except for Turkey. The maximum estimated reduction, of around 70 percent, occurred at traffic stations in Spain and Italy. The maximum estimated reductions of background NO_2 concentrations were also around 60 percent for the different estimation methods. PM10 concentrations were also generally reduced across Europe as a result of lockdown measures and independently of the meteorological conditions, although less than for NO_2[10]. The lockdowns effect on emission reduction had a pronounced effect on people's health. A study showed that over 800 deaths were avoided with improved air quality resulting from the governmental measures taken from the first pandemic wave to limit the spread of the covid-19. Paris, London, Barcelona, and Milan were among the top six cities with the highest number of avoided deaths[11].

The pandemic gave rise to incentives to invest in bicycle-friendly environments. Bikeway networks were expanded and improved, usually with protected cycling facilities that separate cyclists from motorized traffic. Other pro-cycling measures included restrictions on motor vehicles, such as reducing speed limits, excluding through traffic from residential neighbourhoods, banning car access to some streets, and re-allocating roadway space to bicycles. Car-restrictive measures became politically possible, like speed limits or more expensive parking fees, due to the COVID-19 crisis. Overall, monthly cycling levels in both 2020 and 2021 were higher than in 2019, in many places in Europe. The crisis of COVID-19 offered a unique opportunity for many cities to promote cycling. In most cases, the increased support for cycling fit into the cities' previous plans to promote sustainable transport, increased traffic safety, and reduced air pollution, noise, energy use, and CO_2 emissions[12]. The pandemic effect led to more cycling in several countries but a reduction in walking and public transport in most Nordic countries.[13]

An important lesson from covid 19 is that many pro-cycling and car-restrictive policies thought impossible before the pandemic were indeed possible to implement due to the public and political support generated by a crisis. It should serve as inspiration to transport planners, government officials, and politicians to build on those policies in the coming years. Other challenges, although less dramatic and sudden than the COVID-19 pandemic, like environmental, economic, and social crises benefits from initiatives that encourage cycling and walking.

5.3 Promoting active transport

Reducing car dependency through better land use and urban planning, efficient public transport and discourage driving can lead to more walking and cycling.

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[9] NILU Brage: Quantifying the Impact of the Covid-19 Lockdown Measures on Nitrogen Dioxide Levels throughout Europe (unit.no)

[10] Air quality in Europe - 2020 report — European Environment Agency (europa.eu)

[11] Copernicus (2022). More than 800 deaths may have been avoided due to air quality improvement during the first lockdown phase in Europe. Found on internet 7 November 2022: https://atmosphere.copernicus.eu/more-800-deaths-may-have-been-avoided-due-air-quality-improvement-during-first-lockdown-phase

[12] Ralph Buehler and John Pucher (2022). Cycling through the COVID-19 Pandemic to a More Sustainable Transport Future: Evidence from Case Studies of 14 Large Bicycle-Friendly Cities in Europe and North America. Sustainability 2022, 14(12). Found on internet 7 November 2022: https://doi.org/10.3390/su14127293

[13] Statens vegevesen (2022). Nøkkeltallsrapport 2021 Nasjonal reisevaneundersøkelse
Rapport utarbeidet av Opinion AS på vegne av Statens vegvesen og RVU-gruppa, Trafikanalys (2022). Resmönster under coronapandemin 2020–2021 Rapport 2022:5.

Physical barriers: Cycle streets, or boulevards, combine traffic calming with a reduction in motorized traffic and the prioritization of cyclists. For example, by installing semi-permeable chicanes, which provide a horizontal diversion of traffic, in intersections, car through-traffic is eliminated while cyclists can still pass. Rearranging stop signs and rights-of-way can substantially increase comfort and the average travel speed of cyclists. When implemented as a coherent network, such routes can provide a highly efficient, safe, and comfortable solution to accommodate cycling in a space- and cost-effective way. An equally successful and broadly adopted measure is to reduce travel speeds even further to a walking pace, to create living streets. In these street designs, there is typically no distinct allocation of sidewalks and road space. Instead, all road users share the same space, and signalization indicates to drivers that they do not have priority over other road users. Tactical urbanism (Street Plans Collaborative, 2016) uses a broad range of temporary and typically cheap ad-hoc measures, including repainting road markings, rearranging and/or repurposing parking spaces, and using planters and all sorts of objects to reshape the road space to achieve traffic calming effects more quickly. An example of this is Barcelona, that introduced so called Super blocks, that provides the inhabitants to grid for motorized traffic and creates highly liveable, car-free oases for pedestrians, cyclists and residents engaging in all sorts of outdoor activities[14].

Overcome junctions: Intersections or junctions are often the most challenging parts of a journey and are prone to conflicts as the paths of different travel modes cross. There are different physical solutions, for example alterations to the geometry of intersections and regulations of rights-of-way and curb extensions (which extend the sidewalk or curb line out into the parking lane to reduce the effective street width), and corner cushions and bulb-outs, which extend sidewalk space at four-way intersections.

Cycling convenience: Other factors that promotes cycling and walking is trip-end facilities, such as safe parking for bikes. Facilities for changing clothes and showering at workplaces can be important considerations when deciding whether to bike or not. Excellent public transport not only depends on walking and cycling as feeder modes, but also provides a crucial back-up option for active travellers, especially on rainy days and during winters. Bike sharing systems remove further the cost of purchasing a bike, and the burden to own and store it.

Integration with public transport: The integration of cycling in public transport commutes is particularly interesting for reducing door-to-door travel times, particularly in the trips between the transport station and home or the workplace. As a feeder mode, cycling is substantially faster than walking and more flexible than public transport, eliminating waiting and scheduling costs. A comparison of travel times on 25 home-to-work links in the Netherlands indicated that the travel time ratio between public transport and private car can drop from an average of 1.43 to 1.25 hours if the bicycle is integrated in the public transport commute. Cycling integration efforts are currently part of the transport planning strategies of different cities in Europe. In the Flemish region of Belgium, 22 percent of all trips to the station are made by bicycle. In the Netherlands, 39 percent of all trips to the station are made by bicycle and 10 percent of train passengers continue their trips on this mode. In Denmark, 25 percent of train clients use the bike to get too the station and 9 percent in Sweden. In the city of Malmö this number has increased to 35 percent. In Copenhagen (Denmark) and Berlin (Germany), bicycles are allowed in trains and underground transport while in Dresden (Germany), Strasbourg and Lille (France) bicycles are generally allowed on trams[15].

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[14] WHO Europe (2022). Walking and cycling: latest evidence to support policy-making and practice. Copenhagen: WHO Regional Office for Europe; 2022. Licence: CC BY-NC-SA 3.0 IGO.
[15] Guy Hitchcock & Michel Vedrenne (2014). CYCLING AND URBAN AIR QUALITY A study of European Experiences

Green areas: Green spaces, parks and trails, as well as forms of urban revitalization (e.g. promoting shops, restaurants and businesses in former industrial zones in a way that makes them easily accessible by bike and foot), are further options to indirectly promote walking and cycling. In fact, there is growing evidence that the presence of green spaces may not only promote physical activity but also, for example, help to reduce exposure to heat or air pollution, and beneficially affect mental health.

5.4 Promoting public transport

There are relatively few studies which describe the effects of policy instruments for the transfer from car to public transport. It is often difficult to discern clear-cut effects of individual instruments. One important reason is that the instruments are rarely implemented separately, but as part of a larger set, or packages of policies, policy instruments and measures. Pricing and supply of car parking and the redistribution of existing road space from cars to public transport are examples of single instruments with theoretical and demonstrated potential. However, a central conclusion is that no single instrument automatically leads to effects in the form of significantly increased public transport share. Instead, packages of interlocking instruments and actions, within and outside the public transport, are more successful ways of changing the modal split. One has to consider the factors that affect public transport use, understand the given local, regional or national context where previous experiences have been gained, and estimate the degree of transferability[16].

Conclusions from a literature study[17] shows that public transport only works well in relationships where there is a reasonably high demand. Public transport can mainly compete with the car in slightly larger cities, in the order of 70,000 residents and larger or in commuting relationships with extensive travel background. The price for traveling by public transport naturally affects travel by public transport. How much it affects depends on a wide range of factors such as socio-economics of the road user, where the journey takes place and for what purpose. Price reduction seems to have relative little effect on motorists' willingness to choose public transport. Zero rate has been tested in a few places, an experiment in Swedish town Kristinehamn showed that travel in the urban area increased with approx. 100 percent but only with approx. 8 percent in rural areas. In the increase in the urban area however, only 24 percent came from previous car drivers. One way to increase attractiveness is to introduce basic netting. This means that the traffic supply is concentrated to a limited number lines with high trip density and convenient line stretches. It is based on the motto "think tram running bus" (In very recent years, some major cities also have plans to introduce trams). Such a line network leads to shorter journey times for travellers and shorter driving times for the operator, which in turn makes it possible to increase the frequency of trips. Several financial incentives can have a great effect on how one chooses means of transport. This applies, for example, to the travel deduction for trips to/from work, free or subsidized public transport card from the employer and taxation of benefit car. In summary, it can be stated that a distance-dependent travel deduction would have a great effect on public transport and significantly reduce car use. Subsidized card of the employer could also have a large positive effect on public transport, but relatively small effect on car travel. In addition, it would entail a large tax loss for the public sector.

5.5 Parking

The range and price of parking is a very strong control tool for the choice of means of transport. A study from Kista in Stockholm shows how the parking range affects the choice of means of transport.

[16] Joanna Dickinson och Anders Wretstrand (2015). Att styra mot ökad kollektivtrafikandel En kunskapsöversikt. K2.
[17] Bengt Holmberg (2013). Ökad andel kollektivtrafik – hur? En kunskapssammanställning. Bulletin 286 trafik och väg | institutionen för teknik och samhälle Lunds tekniska högskola | Lunds universitet, 2013.

When parking is charged and becomes less easily accessible, car users' habits change advantage of public transport, cycling and walking. With free and approachable car parking 58 percent choose the car, but if parking space were charged only 20 percent choose the car. In the same way, the percentage who chose public transport increased from 32 to 57 percent[18]. The municipalities have a powerful tool in their hands here if they want to influence the means of transport distribution.

A problem for the municipalities is that many parking spaces are located in private land and therefore the price cannot be affected there. However, the range of parking spaces can be affected by the parking standards issued by the municipality.

5.6 Micormobility

In the recent years micromobility has been introduced as a new way of transport in many countries. There is still not an international agreement on how to define *micromobility*. The market of micromobility is still changing quickly and there is still high innovation when it comes to micromobility, therefore it is difficult to find any definition that will be robust over time. Nevertheless, to handle this it is useful to have a definition, even if it might be some differences from country to county, and if it might be changed later. The Norwegian Public Road Administration has defined micromobility as: …*individual travel over relatively short distances, using a light electric vehicle which is basically for one person and/or some cargo*[19].

The introduction of micromobility creates opportunities as well as challenges. Mostly, the challenges are about traffic safety and how small electrical scooters for rent is blocking street space and sidewalks. In this report we will only focus on the effects on local air quality and emission of greenhouse gases.

To say something about how introduction of micromobility influence the air quality, it is crucial to know what kind of transport that are replaced by micromobility. Two studies by TØI in Norway have asked users of electrical scooters how they would have travelled if they not could have used an electrical scooter (Table 1)[20,21]. In cases where the whole trip was done by an electrical scooter, the answers given in the table indicate that in 53 percent of the cases, an electrical scooter replaces walking or biking. In 32 percent of the cases it replaces public transport, and only in 13 percent of the cases the electrical scooters replace cars/taxis. Note, the numbers are different if use of electrical scooter was only for a part of the travel. Also note that this poll only asks for electrical scooters, not all micromobility given in the Norwegian definition. As far as we know, there is no studies quantifying how this affects local air quality. But given the results in Table 1 the introduction of micromobility has some potential to improve local air quality, but most likely the effect is small. This conclusion might change in the future. This depends however on how this new marked is regulated by the national governments as well as local governments in local cities. Even though most focus for regulation is on traffic safety and other aspects besides air quality, local governments should be aware on how the regulations also affect local air quality. In Norway there is established a *catalog of measures* that describes ten advices for how local cities should regulate this new market[22].

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[18] Bob Olausson David Solvin (2019). Restidskvotens påverkan på färdmedelsvalet En undersökning av sambandet för mellanstora kommuner. Thesis. Trafik och Väg Institutionen för Teknik och Samhälle Lunds Tekniska Högskola Lunds Universitet

[19] Kjølberg, Aaland mfl., (2022). Veikart for regulering av mikromobilitet. Statens vegvesen

[20] Fearnley, N., Johnsson, E. og Berge, S.H. (2020b). Patterns of E-Scooter Use in Combination with Public Transport, *Transport Findings.*

[21] Fearnley, N., Karlsen, K., Bjørnskau, T. (2022). Elsparkesykler i Norge: Hovedfunn fra spørreundersøkelser høsten 2021, TØI-rapport 1889/2022

[22] Tiltakskatalogen (2023). https://www.tiltak.no/c-miljoeteknologi/c1-drivstoff-og-effektivisering/delte-elsparkesykler/

Table 1: What ratio of electrical scooters replaces different means of transport.

Context	Replaces walking	Replaces bike	Replaces public transport	Replaces car/taxi
When electrical scooter is main transport (73 % of all travels)				
	47 %	6 %	32 %	13 %
When electrical scooter is used to reach other transport (25 % of all travels)				
Just change the part with electrical scooter	78 %	4 %	14 %	5 %
Would change the whole trip	13 %	6 %	51 %	30 %
Travelling with electrical scooter by night	34 %	2 %	22 %	38 %

6.Environmental zones

The limits values for NO_2 and particles are exceeded in several Norwegian cities and urban areas. While studded tires are often an important reason why the limit values for particles are exceeded, it is exhaust from road traffic that is the biggest source of NO_2 emissions. Road traffic's local environmental problems are particularly large in city-centre areas. In many cases, these areas have experienced a large increase in traffic. At the same time neither the road network, the buildings or surroundings have been designed to deal with the environmental problems that it causes. The main purpose of low emission zones is to reduce exhaust emissions, but it can also be used to reduce noise, road dust, etc.

In Norway, the low emission zone is defined as a geographically defined area, which is exposed to local air pollution from cars, and where the municipality has received consent to introduce a fee for driving[23]. This is somewhat equivalent to what they in Sweden call "miljözon" or what they in the EU call low emission zone. In Norway, the term environmental zone has a somewhat wider scope than a low emission zone and also include other environmental measures than those that only set requirements for the vehicles' emission characteristics.

In December 2016, Norway introduced low emission zones. In the National Transport Plan 2022-2033[24] it is stated:

"Municipalities can establish low emission zones out of consideration for local air quality based on section 13 of the Road Traffic Act and regulations of 20 December 2016 on low emission zones for cars. The regulations do not provide the opportunity to create such zones solely for reasons to climate. As discussed in the climate plan, the government will consider relaxing the conditions for low emission zones, so that these can also be established with climate justification".

In Norway some cities also have zones for tax for using studded tires. This mitigation has the purpose to reduce the emission of road dust from road wear. These zones are not addressed as "Environmental zones"; however, one could argue that it is. This is not discussed further in this report.

[23] Tiltakskatalogen, Lavutslippssone - Tiltakskatalog for transport og miljø
[24] Meld. St. 20 (2020–2021) - regjeringen.no

6.1 Conditions to environmental zones

To be able to introduce a low emission zone, the municipality must present an overview that is specified in regulations on low emission zones for cars. Documentation must be submitted on:

- Extent and spread of local air pollution from cars in the planned low emission zone
- Planned zone size and signage
- Expected effect of the zone on pollution
- System for registration, payment, information, control, enforcement etc.; assessment with regard to privacy
- Application to Vegdirektoratet for granted authority to impose infringement fees
- Planned fee rates and how these are calculated
- Information on how the net income from the zone will be used, for example too public transport, traffic safety or environmental measures.

It is up to the individual municipality whether they want to introduce a low emission zone and there is a possibility for several municipalities to join and establish a joint low emissions zone.

It must work throughout the year and can be introduced for up to six years at a time. A municipality can establish several low emission zones within the municipality, but they must be geographically delimited, coherent, uniform, and signposted. The demarcation is determined based on the areas that are sensitive (number of homes or people staying outdoors in the area) and the location/spread of pollution and other environmental problems. The zones should be of a certain size.

The requirements in the low emission zone will often be stricter than the requirements in the nearby areas. The low emission zone must therefore be separated, and the demarcation must be well-known to those who fall under the various provisions. Control arrangements should also be established to gain the environmental effects that are expected and to prevent that those who break the provisions gain any benefits.

Low emission zones are mainly suitable in parts of cities (and densely built-up areas) that are particularly burdened by noise and pollution from road traffic. It is valuable to introduce restrictions/measures on different urban areas at the same time.

Section 13 of the Road Traffic Act gives the municipality authority the possibility to introduce a low emission zone in a specified area to limit environmental disadvantages from traffic. Planning and establishment require extensive cooperation between the municipality, city/town, residents, and businesses within the relevant zone, as well as the sectors that will introduce the relevant measures.

The individual municipality that wishes to introduce one or more low emission zones must do so by adopting local regulations. Local regulations must have been subject to consultation in the usual way. Several municipalities can join to establish a low emission zone and adopt similar regulations. Establishing the scheme, requires dialogue with the Norwegian Road Administration, which has the authority to give consent to the scheme. It is expected that the municipality takes care of motorists' needs for legal certainty and privacy by creating sound systems for information, payment, control, and enforcement with electronic and manual solutions. Regulations on low emission zones for cars § 4 sets conditions for a municipality to be granted consent from the local road office[25].

[25] Håndbok V724 Lavutslippsone for biler (vegvesen.no)

6.2 Characteristics in the environmental zones

In most of today's low emission zones in Europe, the requirements are aimed at heavy vehicles. The ban/tax is linked to the extent to which the vehicle satisfies the EU's emissions requirements (the Euro requirements) and whether cleaning equipment that removes exhaust particles is fitted. Diesel cars that are prohibited because they belong to an older Euro class can in some cases drive in the zone if a particle filter is retrofitted.

The types of vehicles covered by the zones vary. The measure can be designed as a complete or partial ban on one or more vehicle types. It is possible to implement the measure with a tax scheme, such as in Greater London.

In low emission zones, it is common to introduce measures directly aimed at the vehicles. This can either be in the form of a ban on certain vehicle types that do not meet defined requirements, and/or that polluting vehicles must pay a fee to be able to drive inside the zone.

In local regulations, the municipality can put further provisions on what cars that are obliged to pay a fee. The obligation to pay a fee does not apply too:

1. Zero emission cars
2. Cars approved as emergency vehicles and other cars in the service of the police or the armed forces
3. Cars specially equipped for self-transport of disabled people and cars where the driver or passenger carries a parking permit for disabled people
4. Diplomatic vehicles, in the regulation described as “car with license plate with yellow characters on a blue background”

When establishing low emission zones, control regimes must also be established to ensure that the rules are complied[26]. There are many different systems that are used from camera monitoring and electronic chips to wafers that are connected to a register of the vehicles' environmental characteristics (for example, the Euro requirements).

The specific requirements or measures within an environmental zone can be determined locally based on the area's environmental problems, or on the desired environmental quality, local climatic - and topographical conditions. Possible measures in environmental zones are:

- Traffic restriction; e.g. ban on certain types of vehicles (e.g. heavy vehicles), possibly in certain periods of time
- Parking restrictions; e.g. increased prices, fewer parking spaces, time-limited parking
- Speed restrictions; e.g. reduced speed limits and physical speed-regulating measures such as constrictions and speed bumps
- Road engineering measures; e.g. better provision for pedestrians and cyclists.

Zero emission zones have been investigated in Bergen and Oslo. These are zones where vehicles emitting CO_2 are banned. In Oslo, a zero-emission zone is recently introduced (2022) that will initially include light vehicles, such as cars and vans. Heavy vehicles (over 3,500 kg) will be phased in at a somewhat later date.

Ultra low emission zones (ULEZ) have even stricter regulations than low emission zones where polluting vehicles must pay a fee to be allowed to drive. The most famous example is the ultra low emission zone in London.

[26] Hur ska regelefterlevnaden av miljözonsbestämmelser säkerställas? - Transportstyrelsen

When working with municipal and county plans, comprehensive spatial planning and cooperation between the sectors could be important to overcome the environmental problems. In the plans, provision could reduce car traffic, and a transition to more environmentally friendly forms of transport should be made possible with different measures, such as road pricing and limited driving bans in the city Centre, which have many similarities with low-emissions zones.

Stricter emission requirements for vehicles can also contribute to lower emissions. The initiative Euro requirements and type approval of vehicles has data on the increasingly strict requirements. Euro VI trucks manufactured after 2013, for example, are required to emit only a fifth as much NOx as Euro V (2008)[27]. The differences in emissions in real traffic can be even greater. Testing of both busses and lorries in a realistic driving cycle, shows that emissions were reduced by 90 percent or more for both NOx and PM when switching from Euro V to Euro VI vehicles[28]. While the trucks seem to over-meet the requirements, the situation is the opposite for diesel passenger cars. Measurements show that in real traffic diesel cars can emit 7-8 times more NOx than is foreseen in the Euro 6 requirements[29].

Low emission zones have been introduced in Norway in January 2022, in the event of high air pollution areas in Bergen and Oslo. More information about low emission zones in Europe, and what requirements have been introduced in the various cities, can be found on the EU's website on low emission zones - https://urbanaccessregulations.eu/ .The information in Table 2 below is taken from this website, as well as the various cities' websites.

Tabell 2 Type of requirements in environmental zones depending on country and city

Country and designation	Cities	Year start	Type of requirements for different vehicles that must be met in order to drive in the zone
Sweden Miljözone Link1	Gothenburg, Malmö, Stockholm	1996	Trucks and buses Euro VI requirements
Sweden	Hornsgatan, Stockholm	2022	Passenger cars, minibuses, vans: Euro V requirements by 1.7.22
Denmark Miljözone	Copenhagen, Aarhus, Frederiksberg, Aalborg, Odense	2022	Heavy vehicles >3.5 tonnes. Requirements for registration year. From 2022 at the latest registered 1.1.2015. Vans 2.7.22 after 1.1.2012 and 2025 after 1.9.2016
England Low Emission Zone	14 cities, Greater London, Manchester, Norwich, Oxford	2008	03.2021 trucks > 3.5 tonnes and buses > 5 tonnes must meet Euro VI requirements. Smaller vans and minibuses must meet Euro III requirements. If requirements are not met, a fee of up to £3,000 must be paid.
England Ultra LEZ	London	2019	25.10.2021 all diesel cars (incl. vans and minibuses) must meet Euro VI and the petrol-powered Euro IV. Control via cameras. Operational around the clock.
Germany Umweltzone	70 cities; Berlin, Bonn, Bremen, Cologne,	2008	The cars must be equipped with wafers to drive in the zone. Red color is for the most polluting cars and is no longer on sale. Yellow color has only one place. Green is for electric

[27] NOx-utslipp fra lastebiltransport – effekter av forsert utskifting av lastebilparken - Transportøkonomisk institutt (toi.no)
[28] Busser, Euro VI og avgassutslipp. Status 2016/2017 - Transportøkonomisk institutt (toi.no)
[29] TØI rapport (toi.no)

	Dortmund, Dusseldorf , Frankfurt, Stuttgart		cars and petrol cars that meet Euro 1, diesel passenger cars, trucks and buses that meet Euro 4 (or Euro 3 with a retrofitted particle filter). The wafer costs approx. NOK 130
Germany	Berlin, Darmstadt, Hamburg and Stuttgart	2021	Several cities will tighten the requirements and are working to get the state's approval to introduce a blue wafer with requirements for Euro VI. have introduced these strict rules (2021) often referred to as the "Diesel ban".
Italy Zona a Traffico Limitato	50 areas and 570 municipalities		Varying requirements and duration of the day
The Netherlands	13 cities. Amsterdam		Applies to diesel vehicles and trucks >3.5 tonnes.
	Rotterdam		A: Also applies to buses. R Trucks requirements Euro VI.
The Netherlands	Amsterdam, Arnhem, The Hague, Utrecht		Applies to diesel-powered cars and vans that must meet Euro IV to drive in the zone
	Rotterdam		
Belgium Lage-emmisiezone	Antwerp, Brussels, Gen, Wallonia	2022 2015	Diesel vehicles must meet Euro V, from 2025 Euro VI Petrol vehicles must meet Euro III The exception is a day pass that can be purchased 8 times a year
Scotland, Low Emission Zone	Glasgow, Aberdeen, Dundee, Edinburgh	2022	Local diesel buses must meet Euro VI. This applies from 2022, diesel vehicles and petrol cars must meet Euro IV
Austria Low Emission Zone	Several areas		Wafer system showing the emission standard . In Tyrol, they have an 80 km long motorway where returning diesel-powered trucks >7 tonnes must fill Euro VI
		2023	From 23 the requirement also applies to non-returning vehicles.
France Zone a faible emission	Paris, Lyon, Strasbourg		Paris: Wafer system (Crit'air) from 8:00 - 20:00 weekdays, but all days for heavy vehicles. Diesel passenger cars and light vans Euro V, petrol Euro II.
		2024	Ban diesel cars
		2030	Only electric and hydrogen vehicles allowed.
Finland	1 city, Helsinki		Buses and garbage trucks must fill Euro V
Portugal	1 city, Lisbon	2021 2050	Requirements: Euro V from 06:30 - 00:00. More exceptions. Zero emissions

Spain Zone de bajas Emissiones	Madrid, Barcelona, Sant Cugat		Requires Oblat to run. Diesel Euro VI, Petrol Euro III
Greece	Athens, 2 zones		Small zone: vehicles <2.2 tonnes every other day. Large zone: vehicles >2.2 tonnes must be newer than 22 years.
The Czech Republic	Prague		Vehicles > 3.5 tonnes must apply for a permit. Euro IV required. Zone plan for all petrol and diesel vehicles .

6.3 Environmental zones in Sweden

Sweden was the first country to implement Low Emission Zones (LEZs), as a measure to reduce pollution from vehicles. Swedish cities could from 1992 legally ban heavy duty vehicles from entering "environmental sensitive areas". These are areas struggling with pollution and noise, and at the same time areas with a lot of dwellings and pedestrians/cyclists. After this change in regulations, the cities of Stockholm, Gothenburg and Malmoe worked together constructing a framework for how to implement a LEZ[30]. The Swedish LEZs are now regulated by Trafikförordning (1998:1276)[31]. The main goals of the LEZs were to:

- Reduce the emission contribution from HDVs in central parts of the cities
- Improve air quality in the areas and reduce noise
- Speed up the replacement (or retrofitting) of older vehicles
- Stimulate a technological innovation towards less polluting vehicles
- Contribute to air pollution improvement also outside of the LEZ boundaries. Stockholm, Gothenburg and Malmö implemented their LEZs in 1996. The current LEZs regulate buses and trucks (gross weight >3.5 ton). In general, diesel trucks and buses older than six years are not allowed to enter the Swedish LEZs.

Environmental zones with slightly different designs have been introduced in several European cities, including London, Berlin, Oslo, Paris, Brussels and others. The evaluations carried out mainly concern cities that had large quantities of older diesel cars, and the environmental zones resulted in replacing the oldest diesel cars with newer ones. However, Stockholm's older car fleet consists of almost 90 percent gasoline cars, and an exchange of the older vehicles therefore gives a smaller effect here. Nevertheless, the environmental zone is described as one of the most powerful measures to reduce emissions of exhaust particles and nitrogen oxides, while there is international concern that environmental zones may lead to increased climate emissions through a switch to gasoline cars.

Environmental zone class 1

The basic rule is that a heavy truck or heavy bus may drive in a class 1 environmental zone for six years from first registration, not counting the current year. Exceptions to that basic rule are that vehicles that meet exhaust requirements better than Euro II (from 1 September 2013, better than Euro III) are allowed to drive in environmental zones for eight years, not counting the year of registration. Vehicles that meet Euro VI emission standards may be driven in this environmental zone for free.

[30] Effekter av miljozoner i Stockholms stad
[31] Trafikförordning (1998:1276) | Lagen.nu

Environmental zone class 1 for heavy vehicles is currently available in:

- Stockholm
- Gothenburg
- Malmo
- Mölndal
- Uppsala
- Helsingborg
- Grove
- Umeå

Environmental zone class 2

Environmental zone class 2 includes passenger cars, light buses, and light trucks. In order to drive in environmental zone class 2, vehicles with both spark-ignited engines (e.g. petrol engine) and compression-ignited engines (diesel engines) must comply with Euroclass Euro V or Euro VI. As of 1 July 2022, the requirements for cars with compression-ignited engines will be tightened to comply with Euro VI.

Hornsgatan in Stockholm introduced class 2 in 15 January 2020 as a test to study what consequences environmental zone 2 has in practice[32]. This street has been exposed to problems with high levels of nitrogen dioxide and particles, and both heavy and light diesel-powered traffic contribute with high emissions. The decision to introduce more environmental zones in Stockholm was also motivated by the fact that additional measures were required to meet the statutory environmental quality standard for nitrogen dioxide, but also the sharper environmental quality objectives for the protection of human health.

Environmental zone class 2 for light vehicles on Hornsgatan has been evaluated by SLB analysis in terms of effects on emissions of nitrogen oxides and nitrogen dioxide concentrations[33]. With the help of sensors, the vehicles were categorized down to Euroclass level with emissions for road type of Hornsgatan and driving pattern according to an emission model. It turned out that compliance with the environmental zone's regulations was very poor (17 percent of unapproved light-duty vehicles), but compared to reference streets without an environmental zone, it had nevertheless led to a greater renewal of the vehicle fleet. It was estimated that total emissions of nitrogen oxides in 2020 was reduced by 2 percent, compared to the same year without an environmental zone. In case of full compliance with the environmental zone regulations, the effect would have been 11 percent according to the calculations. For nitrogen dioxide concentrations on Hornsgatan, this corresponds to a reduction of approximately 1 and 4-5 percent respectively upon full compliance. The calculations refer to the situation at unchanged total traffic volume, and thus exclude the effects of reduced traffic flows due to the covid-19 pandemic.

Environmental zone class 3

In environmental zone class 3, the highest requirements are set. There, only electric vehicles, fuel cell vehicles and gas vehicles are allowed to drive. Light and heavy vehicles with the addition that for gas vehicles, emission requirements Euro VI also apply. In the case of heavy-duty vehicles, plug-in hybrids, they may also drive if the vehicle meets Euro VI emission standards.

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[32] R5-utl-miljozon-klass-2-pa-hornsgatan-minoritetsaterremiss
[33] Beskrivning av problem-bilden för halter av kväve-dioxid (NO2) och partiklar (PM10) i Stockholms län (slb.nu)

Summary
Table 3 shows description of national rules for different environmental zones are defined in the Traffic Ordinance (1998:1276).

Tabell 3: Different environmental zone classes.

Environmental zone class 1	Environmental zone class 2	Environmental zone class 3
Heavy trucks and heavy buses comply with Euro class 6 from 1 January 2021	Passenger cars, light trucks and light buses will meet Euro class 5 or 6 in 2021. On July 1, 2022, the requirements for diesel cars that must then meet Euro class 6 will be tightened.	Light electric and fuel cell vehicles and gas vehicles that comply with Euro class 6. heavy-duty vehicles that are plug-in hybrids and meet Euro class 6;

6.4 Environmental and climate impacts
Low emission zones have been seen as an effective means of reducing air pollution from car traffic in exposed urban areas. When introducing the zones, model calculations of possible effects are usually made, either on NOx or particles (PM10 and PM2.5). The calculations are often based on what changes in traffic and vehicles can be expected because of the restrictions in the zone.

It has proven difficult to reach as large improvements in air quality through actual measurements as what the model calculations show. Considering that there are over 250 such zones in Europe, there have been few studies that have scientifically evaluated the effects of low emission zones. Methodologically, it also turns out to be complicated as many different factors affect air quality, for example the daily variations in meteorology. Other factors can be changes in the car fleet and traffic composition for reasons other than the low emission zone, changes in the economy etc. This can give false results. The zones are also often differently designed with regard to which vehicles are included, thus it can be difficult to carry out meta-analyses and draw general conclusions.

As the most polluting vehicles are phased out and air quality improves, the effect of a measure such as a low emission zone also diminishes. This means that the effects that were found from low emission zones in the early 2000s are perhaps even more difficult to achieve today. When looking at scientific evaluations of effects, later studies therefore have a higher relevance than early studies.

A study of 48 low emission zones in Germany in 2007-2009, it was found that the zones result in a rather small (but still significant) reduction of NO_2, NO, and NOx[34]. However, in a review of the effect of low emission zones on air quality[35], the challenges of evaluating such zones are highlighted, as well as a review of studies that mainly use air measurements to evaluate the effectiveness of low emission zones in five EU countries (Denmark, Germany, the Netherlands, Italy and the UK). Calculations show that the zones in Germany have only led to a reduction in the pollution level by a few percent. Cyryes et al.[36] also summarizes various surveys from Germany. Originally, the low emission zones in Germany were created to reduce particulate matter. For PM10, the studies indicate a decrease from 15 percent to no effect at all. Fewer studies have examined the effect for NO_2, and the actual effects found are small. The greatest effects of the low emission zones can be found on Black Carbon (soot), where most studies report significant reductions.

[34] Morfeld et. al 2014 https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0102999
[35] Holman et al. 2015 https://www.sciencedirect.com/science/article/abs/pii/S1352231015300145
[36] Cyryes et al. 2018 https://pubmed.ncbi.nlm.nih.gov/29761364/

The low emission zone in London was introduced in 2008 and is the world's largest. The model studies prior to implementation expected a decrease in the concentration of PM10 throughout London close to 50 percent and 20 percent for NOx. However, studies based on actual measurements show significantly lower effects. Ellison et al.[37] studied the period 2001 to 2011 and they found that traffic in the zone increased in the first years after its introduction. At the same time, it actually led to vehicles with lower emissions using the zone. This resulted in a decrease in PM of 2-3 percent compared with a decrease of one per cent outside the zone. For NOx, they observed no decrease.

In Paris, it was estimated that the low emission zone would result in an approximately 60 percent reduction in the number of residents who were exposed to NO_2 above the limit values from 2015 to 2019, and an even greater reduction if the zone were extended. The analyzes estimated that with the implementation of the stricter requirements for access to the zone, emissions of NOx from passenger cars in 2024 would be 76 to 87 percent below 2016 levels. However, studies based on actual measurements have not been found.

Panteliadis et al.[38] found significant effects of low emission zones in Amsterdam for al pollution compounds. They used measurement data from before and after the introduction of the low emission zone (2007-2010) and corrected for differences in meteorology and background concentrations. The total reduction for PM due to the zone was approximately 5.8 percent and for NO_2 and NOx by 4.9 and 6.4 percent respectively. Other studies have not been able to find similar positive results[39].

Given that the measure leads to reduced traffic in the zone, traffic safety and accessibility/barrier effects could be improved for pedestrians/cyclists in the zone. It is well documented that air pollution has a harmful effect on the population's health, but the effectiveness of political measures aimed to reduce pollution is less explored. A study from Germany[40] takes advantage of the fact that low emission zones have been introduced at different times. Using register data on outpatient healthcare and hospitalizations, it was found that low emission zones reduce the number of patients with cardiovascular diseases by 2-3 percent. This effect is particularly pronounced for those over 65. The findings suggest that low emission zones can be an effective way to reduce air pollution and improve health. Other studies suggest the same.

However, a study by Sarmiento et al.[41] finds that the positive effects of low emission zones to reduce pollution are systematically overestimated. The study also shows that the zones can create negative effects outside the zones and that the documented health effects are more than eaten up by lower well-being due to the restrictions in the zone. In the article “No-one visits me anymore ': Low Emission Zones and social exclusion via sustainable transport policy", Vrij and Vanoutrive[42], people's experience of living in a low emission zone was studied. Some express that they feel burdened by friends and relatives outside the zone who want to visit them. The zone also has a greater negative impact on mobility for low-income families, who are less likely to replace their car. Bernard et al.[43]

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[37] Ellison et al (2013) https://www.worldtransitresearch.info/research/4831/
[38] Panteliadis et al. (2014) https://www.researchgate.net/publication/260027369_Implementation_of_a_low_emission_zone_and_evaluation_of_effects_on_air_quality_by_long-term_monitoring
[39] Lavutslippssoner i Europa. Krav, overvåkning og luft kvalitet - Transportøkonomisk institutt (toi.no)
[40] Margaryan (2021) https://www.sciencedirect.com/journal/transportation-research-part-a-policy-and-practice/vol/153/suppl/C
[41] Sarmiento et al. (2021) https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3857614
[42] Vrij and Vanoutrive (2022) https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3857614
[43] Bernard et al. (2020) https://link.springer.com/article/10.1007/s11869-022-01243-7

conclude that low emission zones help to reduce air pollution, especially in cities where pollution is high, but such zones are ineffective when it comes to reducing congestion problems.

6.5 Costs

The costs of introducing low emission zones will vary with the type of measure that is chosen, as well as the requirements one sets for effects. The area's environmental problems before the relevant measures are implemented, will also affect the costs. One type of cost is the direct cost of signage and enforcement of the restrictions in the zone, as well as the costs for road users who are inconvenienced and who have to switch to cleaner vehicles etc. It is not obvious that the benefits are always greater than the costs.

7 Future vehicle fleet - electrification, digitalisation, and automation – example from Norway

7.1 Characteristics in the current vehicle fleet

The Norwegian Road Federation has published the report "Personbilen og bilparken i endring, 2000-2022[44, 45]. This report describes the radical changes in the Norwegian car population throughout the last 20 years. In year 2000 there were registered 88 379 petrol cars and only 197 electric cars. However, by first term of 2022, there were registered 2 419 petrol driven cars and 54 162 electric cars. Similar development is shown in all the Scandinavian countries, and in fact all over the world.

Since year 2000, the private car population has increased with about one million cars. Approximately the same amount as the Norwegian population. By the same period, 850 000 petrol cars are taken out of the population, while these mostly are replaced with diesel powered cars. Since year 2000 population of private cars with a diesel engine has increased with about a million.

The last 20 years of the Norwegian car fleet, describes a development from petrol, trough diesel, into electric driven cars. Today the electric cars represent about 18 percent of the total car fleet in Norway, which correspond to 2,7 million private cars (October 2022).

Today 77,7 percent of all new registered private cars are fully electric. Petrol and Diesel represents about 8 percent of the registered cars so far this year. In volume this represents 90 028 electric cars, and 7 587 petrol and diesel cars. Plug in hybrids (PIH) in combination with a petrol engine represents 9,6 percent of the car population, corresponding to 29 671 registered vehicles.

88,8 percent of the registered new trucks (from 7,5 ton), were year 2023 diesel combustion engines. Only 6,55 percent are fully electric. In volume this represents 3 411 diesel trucks, and 252 electric trucks. In 2021 there were only registered 51 electric trucks. 76,5 percent of lorries between 3,5 to 7,5 tons were registered with diesel combustion engine. 22 percent of the registered vehicles were fully electric. In volume this represents 16 927 diesel lorries and 4 865 fully electric respectively. 53,3 percent of the registered buses were fully electric, while 44 percent of them where diesel buses. In volume this represents 286 registered electric buses and 236 traditional diesel driven buses.

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[44] Personbilen i endring
[45] Registreringsstatistikken | Opplysningsrådet for veitrafikken (ofv.no)

7.2 Driving forces for development

Economical stimulations are the clearest factor for changing people's behavior for buying cars. Throughout this period there has been several changes in the Norwegian taxation policy for registering av new car. In 2007, the Norwegian government changed the registration tax for new cars, in favor of diesel driven cars. At this period, the reason was that it was pronounced that diesel cars would contribute to lower CO_2 emissions, and the diesel engine was seen as more sufficient. Petrol driven cars reduced by 850 000 and the population of diesel cars increased with about a million. This was the reason, in combination with few electric car models represented on the market and none of them comparable with a "traditional" private car that served people's needs in a car.

In today's political climate however, these earlier conclusions are seen as wrong. To stimulate the zero-emission market, there has been a broad political agreement in Norway to give electrical cars benefits, in other words given amnesty from taxation when registering. The result is that the electric car fleet has increased dramatically since 2012. The Norwegian government has in its proposal for state budget in 2023 introduced taxation for electric cars for the first time. This, together with more electrical car models, range and charging infrastructure, has result in the fact that it is now a minority who buy traditional cars with combustion engines, and that the electric cars are the most common new car sales.

7.3 Impact on air quality

With the electrification, the cars have gotten bigger, longer, and heavier. In year 2000 an electric car was about 3 meter long, while today an electric car is on the average about 4,6 meters long. The same development is shown in weights; twenty years ago, the electric car weight was about 960 kg, while it is about 2000 kg on average today. A heavier vehicle fleet can lead to increased wear and turbulence of wear particles harmful to health[46]. However, with the reduction of the exhaust emissions and the share of studded tires, it seems that the air quality in total will be better.

In the last years changing in car fleet has a big influence of emission of exhaust gases. For person cars electrification is important, but also the change from diesel engines to petrol engines and introduction of new cleaning technology as Euro 6 standards (especially for diesel engines), have had a great impact. For heavy-duty vehicles the introduction of Euro VI technology for diesel engines in 2014, has obvious been important for reducing the emission of NOx. A heavy vehicle with Euro VI technology has approximately 90 percent lower emission of NOx than a similar heavy vehicle with Euro V technology. This development in the car fleet has been important for de historically reduction of concentration of NO_2 in Norway. In addition, the development of technology and the future car fleet in near future is expected to reduce the emission of NOx significantly. This is also predicted in several forecast calculations in Norway. In Bergen city for example, the annual emission of NOx is expected to be reduced from 764 tons to 77 tons from 2019 to 2030 corresponding to a predicted reduction of approximately 90 percent over 11 years[47]. It has also been calculated that in the Oslo areal, containing neighbour municipalities, the annual emission of NOx is expected to be reduced from 4 725 tons to 2 786 tons from 2019 to 2025. A predicted reduction of approximately 40 percent over 6 years[48].

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[46] Ongoing research project NorDust2, Nordic Road Dust Research Project 2 | Vejdirektoratet (nordfou.org)

[47] Revidert tiltaksutredning for lokal luftkvalitet i Bergen, Torleif Weydahl og Britt Ann Kåstad Høiskar NILU-Rapport-Revidert-tiltaksutredning-for-lokal-luftkvalitet-i-Bergen.PDF

[48] Tiltaksutredning for bedre luftkvalitet i Oslo 2020 – 2025. Dreiebok (oslo.kommune.no)

The reduction of NOx emission from the car fleet is an important reason why the concentration of NO_2 in air quality has been reduced. It is believed that NO_2 will continue to be reduced the following years. However, it should also be noted that this is triggered through mitigations like low emission zones, urban planning, and legislations. It can also be strongly emphasised with different kind of mitigations or politics.

8. UN's Global goals

Nordisk Vejforum (NVF) has given all the working groups the mission to relate the work that has been done in this context, to the United Nations sustainable development goals, Figure 3: The 17 United Nations sustainable development goals.. Below is some short reasonings on how the knowledge above relate to these goals.

Figure 3: The 17 United Nations sustainable development goals.

Global goal 3: Good health and well-being[49]

The improvement of local air quality does more or less meet the UN's sustainable development goal 3 by definition, as maintain good health is the purpose of improving good air quality. UN has specified among the goal targets: "*By 2030, substantially reduce the number of deaths and illnesses from hazardous chemicals and air, water and soil pollution and contamination*". Even though this is global goals, this is also relevant in the Nordic countries as the level of air pollution exceeds WHO guidelines in several Nordic cities. In Norway, air pollution was listed as one of the ten largest health

[49] Goal 3: Good health and well-being | Sustainable Development Goals | United Nations Development Programme (undp.org)

challenges in 2018[50]. Institute of Health Metrics calculate that globally exposure of PM2,5 caused 4,1 million deaths in 2019[51].

Global goal 11: Sustainable cities and communities[52]
Strategies and mitigations that aims to improve local air quality will in most cases also support UN's sustainable global development, goal 11. Among the goal targets here we find: "*By 2030, provide access to safe, affordable, accessible and sustainable transport systems for all, improving road safety, notably by expanding public transport, with special attention to the needs of those in vulnerable situations, women, children, persons with disabilities and older persons*". When this goal is achieved, a following consequence is better local air quality.

Global goal 13: Climate action[53]
In most cases, emissions sources for local air pollution is also the source of greenhouse gases. Therefore, UN's global development goals 3 and 13 are mostly coinciding. However, there are some cases where goal conflicts occur. Densifications of cities would reduce the need of transport in cities and therefore reduce emission of greenhouse gases. But densifications could also locate residents in the most polluted areas and might lead to more people getting exposed to harmful air pollution. In these cases, all consequences should be considered together.

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50 Notat Folkehelseutfordringer (fhi.no)
51 Institute of Health Metrics and Evaluation (2020). Global burden of 369 diseases and injuries in 204 countries and territories, 1990-2019: a systematic analysis for the Global Burden of Disease Study 2019. Lancet 396(10258):1204-1222.
52 Goal 11: Sustainable cities and communities | Sustainable Development Goals | United Nations Development Programme (undp.org)
53 Goal 13: Climate action | Sustainable Development Goals | United Nations Development Programme (undp.org)