Report WP 4

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1 INTROCUCION

A cost-benefit analysis is a way of systematically summarize and weigh social benefits against social costs of and investment or a policy (for instance dynamic prioritization of freight traffic in bus lanes). All effects, benefits and costs should be included, irrespective of to whom the benefits and costs accrue. While a private person's economy, a firm's economy or the government's budget only includes the effects that affect the individual, the firm or the state's finances, the so cost-benefit analysis includes all effects that affect any individual or form in the society. With "generating social benefits" we will mean things as improving accessibility (making activities and services easier to reach by e.g. decreasing travel times or changing the land use) and improving people's health (e.g. reducing emissions or traffic accidents). "Social costs" are simply everything that is negative, including monetary costs (not really because spending money is bad in itself, but because it represents resources which could have been used for something else), but also less tangible things like emissions, accidents, health problems and carbon emissions.

The effects in a transport CBA typically include changes in travel times, travel costs, traffic safety and emissions "translated" to SEK using socioeconomic values, which are based on measurements of the citizens' and carriers' willingness to pay for, for example, shorter travel time or safer traffic. Thus, all effects - or utility's in socioeconomic terminology - can be summarized and compared to the cost of the policy, and different alternative policies can be compared to each other. The term cost here does not include monetary costs but also costs in terms of, for example, increased travel time or increased emissions.

Note that in the long run, accessibility improvements in terms of changes in travel times and travel expenses of travelers and transport buyers do not extend to the economy to the labor market and housing market.

In this sub-study, the socio-economic benefits and costs of a number of different policies are analyzed with the aim of streamlining traffic logistics for freight transport in Sweden's two second largest city Gothenburg. Because we analyze several possible policies, the analysis helps to rank the different policies: that is, it helps to find the policies that generates the greatest benefits relative to the cost of the whole community. The costs could in this case be longer travel times for the buses. It is not certain that all policies we evaluate are not politically feasible at present- but the purpose of this study is to provide support for the development of new ideas in the longer run.

2 SOCIAL COST-BENEFIT ANALYSIS OF PRIORITIZATION OF BUS LANES

Bus lanes are commonly found in cities. Permission to use them is often granted to other categories of vehicles such as taxis, diplomatic cars, cars used by disabled persons. The permission can be extended to certain categories of freight vehicles to create incentives. Vehicles would benefit from higher speed especially if the permission applies to peak hours

In both Stockholm and Gothenburg there are plenty of bus lanes. If these are used by "too few" buses (or if the occupancy in the buses is low) relative to the capacity, the road space will not be utilized in the most efficient way. From a socio-economic point of view, there are "too few" vehicles using the bus lanes if the total travel time of all passengers and goods in all vehicles on the road (cars, buses and trucks) would decrease if more vehicles could use the bus lanes. Or more accurately, if the social value of the increased travel time for some vehicles (including buses) would be lower than the social value of the reductions in the travel time for other vehicles (including truck), the policy would be socially beneficial. However, buses have in general high values of travel time, in particular if they have high occupancy rate, and so long travel time for a bus would have a high social cost.

As the number of buses and congestion varies by time of day and season, capacity utilization can also vary with time of day (as well as seasons). Hence, it is likely wise with a dynamic prioritization of the most valuable traffic.

Professional travel also has high valuation of travel time. It can therefore be efficient to allow some freight traffic to use bus lanes. Then the travel time and travel time uncertainty will decrease for the freight traffic that may use the bus lanes - but also for travelers and transport buyers in the other lanes, as part or all freight traffic diverts from them. The disadvantage is that the buses may be slowed down, so if it's economically efficient to let some or all freight traffic use bus lanes at all or some times, depends on how much longer travel time the buses get, how thee bus operator costs is affected (for example, in the off of higher capital costs and staff costs), and how many travelers get longer travel time.

The reason that it is economically efficient to let freight traffic and not private cars use the bus lane is that the value of travel time on average is considerably higher for freight traffic than for passenger transport. This is due to several factors, including storage costs and the carrier's capital costs and driver wages. Prioritizing freight traffic in private traffic can therefore increase socio-economic efficiency.

The socio-economic analysis of the policies described below will weigh all benefits in terms of improved travel time for all travelers and carriers, by any mode such as extended travel time for bus passengers and increased costs for the operator. Please note that the benefits of private companies are as important as public operators' benefits or travelers. It's not because we particularly care about private firms, but because in the long-run corporate firm's profits end up with individuals. With perfect competition (which is a standard assumption in economics), firms' profits are also zero in the long run.

3 THE CASE STUDY

In both Stockholm and Gothenburg there are plenty of bus lanes. If these are used by "too few" buses relative to capacity, it means that the road space is not utilized in the most efficient way. To use the road space more efficiently is might be wise to let more traffic use the bus lane. The two questions that then arise are: 1) how much more traffic is most efficient to include in the bus lane and 2) which traffic could be prioritized to be able to use the bus lane?

The first of these two questions will be analyzed with model simulations described in Section 4. The answer to the second question is: "the traffic that value the travel time reductions arising from using the bus lane highest". This means essentially that we should let the vehicles with the highest value of time use the bus lane. Note again, that it does not matter, from the socioeconomic point of view whether it is the private traffic, traffic generated by public organizations or by private firms. This is not because we care about private companies making profit, but because in the longer run the profit will trickle down to individuals, and the profit will be zero on a perfect market (with perfect competition: no monopoly power, strict profit maximization, no distortionary taxes, no increasing returns to scale, free entry for new firms, these are standard assumptions in economics). Hence, in the long run the benefits for private companies with spread out in the economy to the citizens.

Now, trucks and trucks with trailers will have on average high values of time, because reduced travel times will lower the storage costs, the carrier's capital costs and driver wages. For this reason, it is probably efficient to let trucks use the bus lane. As we will see, there is another reason for letting the trucks with trailer use the bus lanes: they are more similar to buses than other traffic, in terms of driving patterns, speed and size. Hence separating both buses and trucks with trailers from the rest of the traffic improves the rhythm of the traffic and increases the speed of all traffic. Moreover, mixing the trucks with trailers with the buses in the bus lane does not reduce the speed of the buses to a large extent, because they behave so similar. In other words, mixing different types of traffic reduces the capacity of the road.

To simulate the effect of letting trucks use the bus lane we use the road stretch on Kungälvsleden, between Hisings Kärra and Tingstadstunneln, as a study object, according to the map in Figure 1. Figure 2 shows the lanes of the study object in more detail. Note also that the most important bottle neck, increasing the travel time on the road stretch is in the Tingstadstunneln itself. This bottleneck is implemented in the simulation model. Upstream this bottleneck dynamic congestion will build in the morning peak, in terms of ques building up.

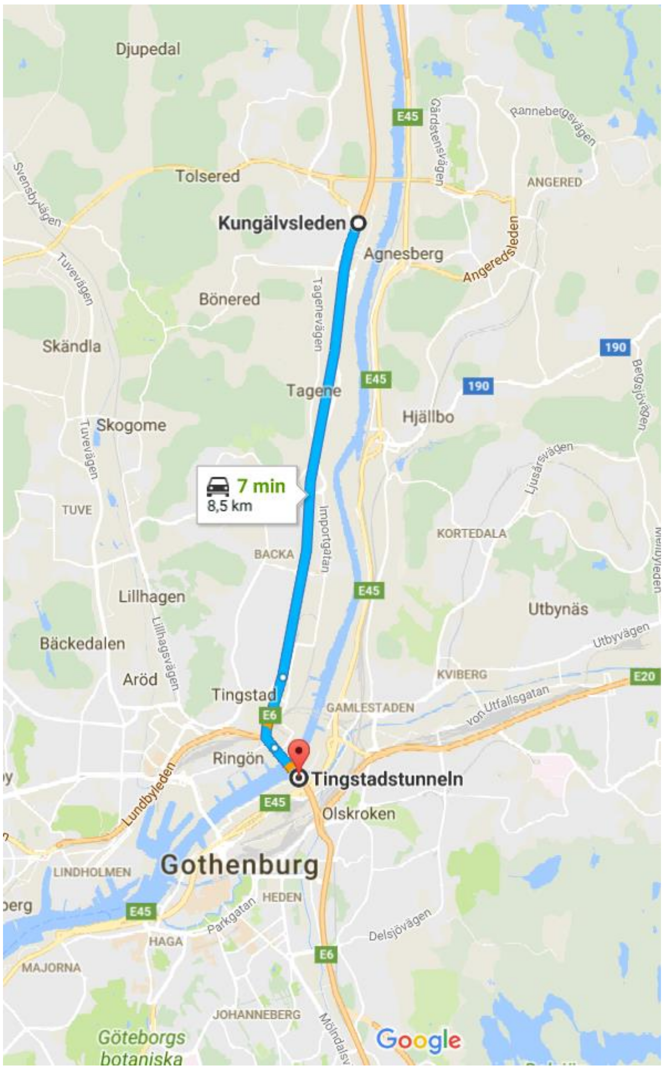

Figure 1:

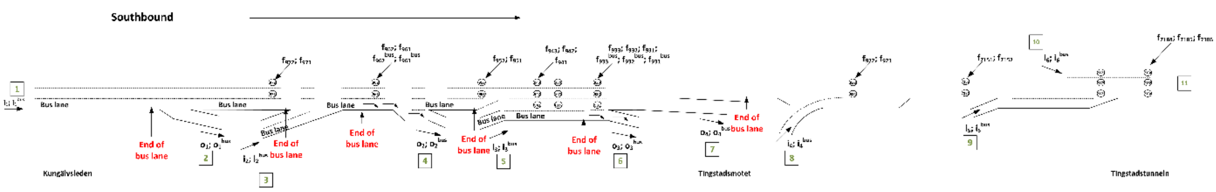

Figure 2:

3.1 How do we make the cost-benefit analysis?

To conduct a cost-benefit analysis, two steps are needed. Firstly, one needs to make a forecast of the impact of the policy on the traffic volume and travel times. The second step that is a calculation of the costs and benefits for the society based on these.

Step 1: Forecast of the impact of the policy on traffic

In a cost-benefit analysis, the effects are calculated from a scenario forecasting effects on travel volumes and travel times for different types of traffic. The effects are forecast by first simulating travel times in a base forecast, which in our case is identical the present traffic situation. Then we also make a forecast of the travel times and volumes for all vehicles assuming that the policy that we want to evaluate (e.g. allocation of bus lanes to freight traffic) has been implemented. The forecast of the effect of the action makes it possible to calculate the difference in travel time between the two simulations for each vehicle.

In Sweden, Trafikverket owns the transport forecasts models, which include all modes of transport, Sampers for passenger journeys and Samgods for freight transport. The purpose of common models is that all modes of transport and all parts of the country have common forecasts and broadly comparable investment cost-benefit analyses.

However, all the Traffic Administration's models Sampers and Samgods are static, i.e. they cannot model effects on travel times in high congestion in an accurate way. There is a minor issue for calculations outside the metropolitan areas, but not in a project modelling effects of reduced congestion such as the present. In this project, we therefore use the forecast / simulation model Mezzo. Mezzo can accurately forecast the effects on travel times of reduced congestion, for example due to the policies allowing trucks to drive in bus lanes. Using another forecast model is not a problem for the policies we are going to analyze should not be compared with national investments. The key is that we use the same model for all actions we analyze - so that they are comparable.

In the simulation model Mezzo there is a time value for each vehicle or group of vehicles. The time value tells you how much one minute longer or shorter travel time is valued in time by just this vehicle. In cases where the price varies between different transport options, the time value will affect the driving behavior of travelers or carriers. Then the values of time in the transport model should be consistent with the values of time we use in the valuation step (step 2, see below). However, in this project we do not assume pricing polices so this is not a problem, since it the value of time does not then impact the behavior of the trucks.

The effects of a road traffic policy such as allowing trucks to use the bus lane can make road users and carriers adapt. This adaptation may be to include changes in the route choice, to change the choice of departure time (for example, distribution traffic can change the time to drive during the day rather than at night or in the off-peak), or to change the destination. It may also be to streamline transports, fill each truck up more or less, so that fewer trucks per day is needed.

In this project, we assume in the first step that no adaptations in terms of mode choice, destination choice, or number of trucks are made, either among travelers or among carriers. We therefore have the same traffic volumes by time of day in all scenarios, regardless of the policy. We only model the changes in the travel time for trucks, buses or passenger cars. Now, the forecast model that we use cannot model the effects of increase travel time reliability. Hence, we will only model the effect of changes in travel time. Hence, benefits or costs changes only because travel time changes.

Step two: valuing the travel time savings by mode

In a second step, the effects are translated to monetary terms. The time changes are valued in monetary terms using the value of time – which is the monetary value of a travel time reduction. The value of time differs between types of traffic but also between vehicles. Figure 1 shows an example of a value of time distribution for private passenger cars. It demonstrates a large variation between trips and drivers. There is a corresponding variation also among trucks and other professional traffic.

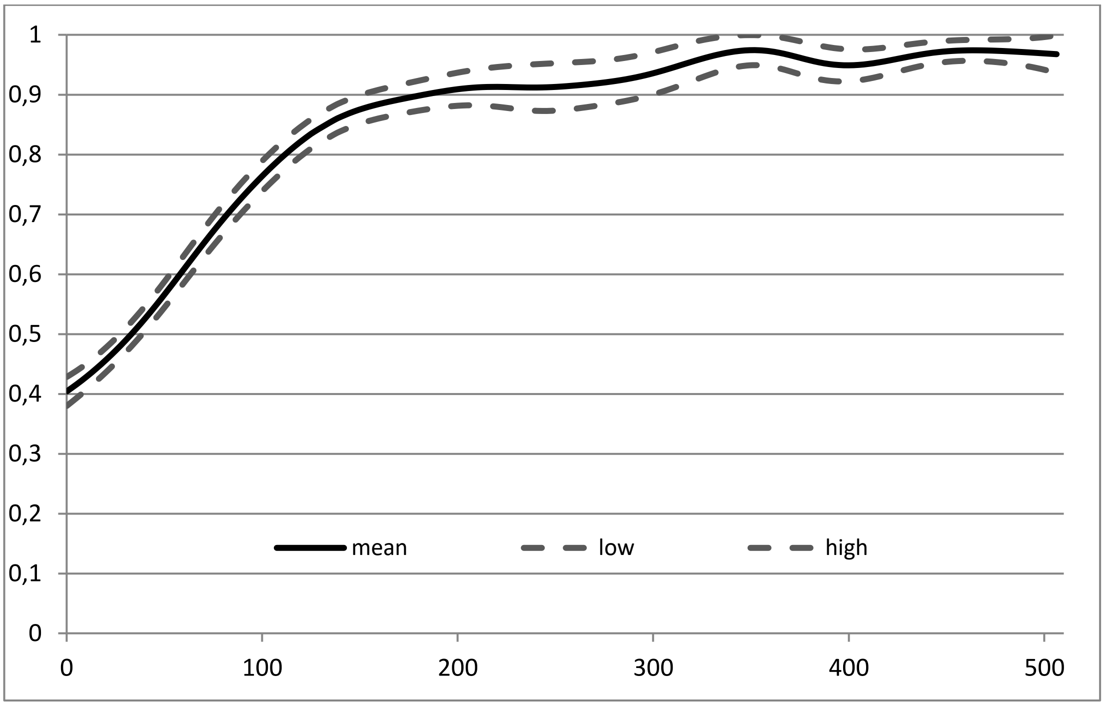

Figure 3: Example of a value of time distribution (SEK/h)

In the Swedish guidelines there is also a value of travel time variability, the value the traffic assign to more stable and predictable travel times. However, this cannot be used in this study because we cannot mode the effects on the travel time variability.

In Sweden, the social cost for changes in road safety (accidents) and health-related emissions are derived from the ”value of statistical life” in the guidelines, while the valuation of $CO2$ is based on political decisions and target levels (a so-called ”shadow price”). However, since the traffic volume does not change in this project, this will not impact our cost-benefit analysis. The valuation is social CBA is always *citizens' and firms own valuations*, rather than the weights of, say, decision makers or planners.

The valuations are based on market prices, if available. Since there is no market for travel time or delay time, we must use other methods. These other methods are derived from data on how drivers and carries behave in the transport sector. IN other words: what a representative sample of travelers and carriers is willing to pay to achieve the effect or benefit in question.

In the cost-benefit analysis in the transport sector, one usually strives to follow the cost-benefit principles, guidelines and valuations used in the national infrastructure planning and which are developed within the framework of the ASEK group. For passenger transport, we have considered it to be an advantage to apply the ASEK recommendations because they are the result of many years of research and development, have been exposed to significant robustness.

4 VALUING CHANGES IN THE TRAVEL TIME

To value the time of truck and trucks with trailer we use values from described elsewhere in the appendix. The average value of time for trucks with trailer is 397 SEK/h. This value is computed based on the assumption that 75% of the trucks with trailer are 60 tonnes, and they have an average value of time of 407 SEK/h. The other 25% are 40 tonnes and they have the average value of time of 365 SEK/h.

The average travel time for trucks without trailer is 283 SEK/h. For passenger cars with trailers, we assume that they are all professional traffic similar to passenger cars, which according to the ASEK guidelines has value of time of 312 SEK/h.

Passenger cars without trailer include both private and professional traffic. From the congestion charging system in Gothenburg we know that approximately 20% of the passenger cars is professional traffic (the car is owned by a legal person). Drivers making private trips have a value of time of 93 SEK/h and professional traffic using passenger cars has the value of time 312 SEK/h. Assuming that 20% of the passenger cars are professional traffic results in the average value of time of 137 SEK/h for passenger cars.

For the buses, we assume that the cost per hour of the drivers is 250 SEK and that the capital cost is also 250 SEK/h. The value of time for passengers is according to the ASEK guidelines 74 SEK/h. Assuming 54 seats per bus and on average 100% of these seats occupied in the peak and 30-50% in the off peak, the average value of time of the bus is 2198 SEK/h.

5 SCENARIOS AND COST-BENEFIT ANALYIS

5.1 Base scenario

To calculate the benefit of a scenario letting trucks use the bus lane, we need to compare each of the scenarios with a base case. The base case is the present situation with two democratic lanes (that can be used by any vehicle) and one dedicated bus lane. Figure 4 shows the traffic volume by hour for all traffic types on the road stretch we model in this study. To improve visibility the passenger car traffic volume is divided by a factor 5 in the figure (hence only 20% of the passenger car volume is shown). It is clear that the passenger car traffic demonstrates a clearer peak pattern profile, with distinct peaks in the morning and in the afternoon. The trucks without trailer are peaks at 14-15, just before the afternoon peak for passenger cars begins. The volume of trucks with trailers, however, peaks during 19-20, after the afternoon peak for passengers, and is lowest during the afternoon peak. The bus volume is pretty stable over the day. Car trailers are highest in the afternoon peak.

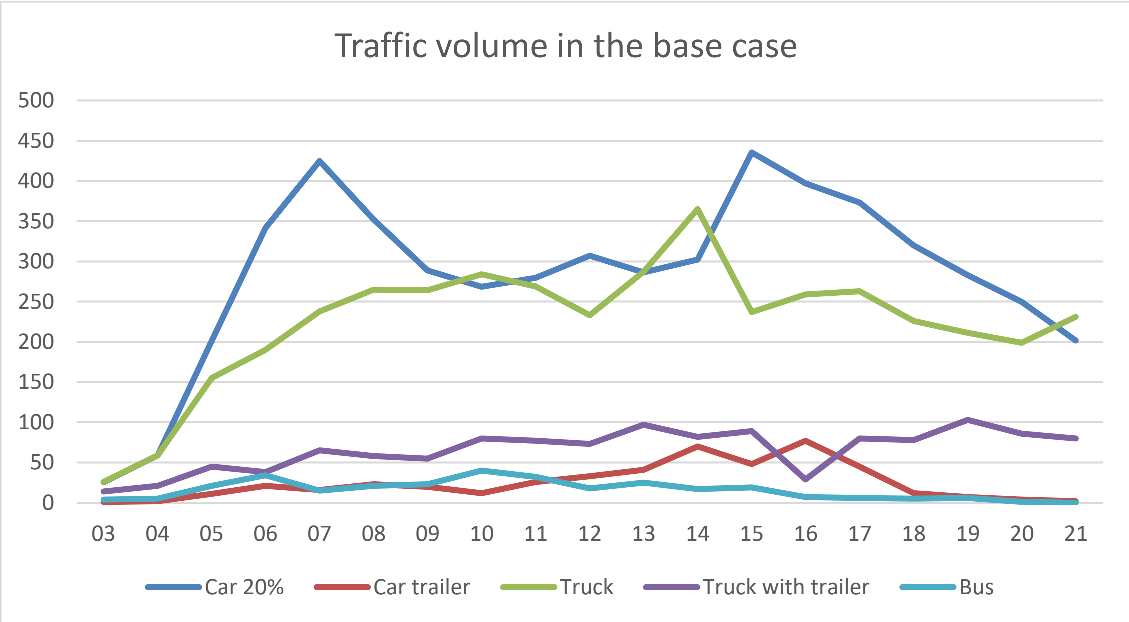

Figure 4: The time of day distribution of different vehicle types. Base scenario 1.

5.2 Scenario: all trucks in the bus lane

In the first scenario we now assume that all trucks (with and without trailer) are allowed to use the bus lane. The average travel time changes by type of traffic and time-of-day is shown in Figure 5.

We see how the travel time reduces in the peak for all types of traffic, except for the buses. This is essentially because the capacity in the peak increases for all types of traffic but for the buses. The travel time for the bus also increases in the evening, because then the volume of trucks with trailers is relatively high. Approximately 80% of the trucks and trucks with trailers use the bus lane.

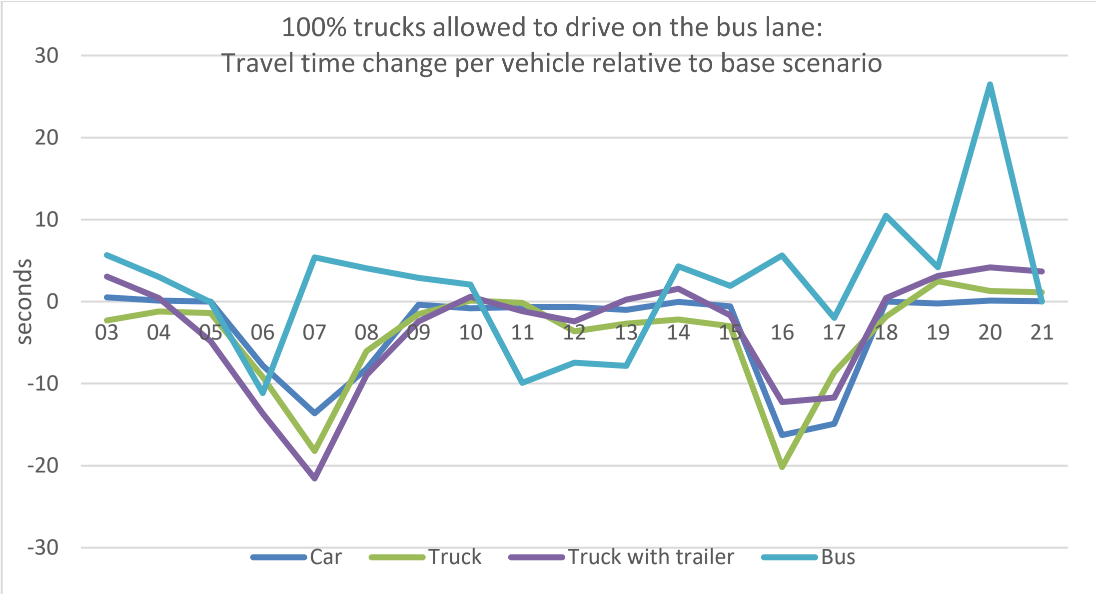

Figure 5: The time change in scenario 2.

Table 1 summarizes the travel time gains and the benefits over one day translated into monetary units. We see that travel time reduces 35h for passenger cars and increases almost nothing for the buses passengers. Light trucks also gain travel time. Light trucks gain 1350 SEK day and trucks with trailers 434 SEK per day. Hence, the net benefit of letting the trucks use the bus lane is 7244.

There is no cost associated with letting traffic using the bus lane to take into account.

Table 1: Travel time changes and benefits and cost of different policies

	Passenger cars	Passenger cars with trailer	Light trucks	Trucks with trailer	Buses
VTT	137	312	283	397	2198
2: All trucks in the bus lane					
Travel time gain (h)	-34.93	-2.15	-4.77	-1.17	0.01
Travel time gain (SEK/day)	4779	672	1350	464	-21
Total benefit (SEK/day)					7244
3. Three democratic lanes					
Travel time gain (h)	-9.47	-0.83	-7.33	-1.78	0.04
Travel time gain (SEK/day)	1295	258	2076	705	-185
Total benefit (SEK/day)					4149
4. 100% trucks without trailers can drive on the bus lane					
Travel time gain (h)	-16.53	-0.98	-1.05	-0.36	0.23
Travel time gain (SEK/day)	2261	306	299	144	-1037
Total benefit (SEK/day)					1972

5. 100% trucks with trailers allowed to use the bus lane					
Travel time gain (h)	-24.70	-1.43	-3.16	-0.40	0.12
Travel time gain (SEK/day)	3379	448	895	158	-541
Total benefit (SEK/day)					4338

5.3 Three democratic lanes

In the next scenario we assume that there are no bus lanes at all, and assume that all lanes can be used by all traffic. The trucks gain most from this policy but the passenger cars and the buses lose travel time. Figure 6 shows that buses are slowed down particularly in the evening peak. Only about 30-40 percent of the trucks and the buses use the bus lane in this scenario. From this we lean that one can question the efficiency of having bus lanes dedicated for buses only, because it implies that the road space is not used as efficient as possible (the bus lane is too empty).

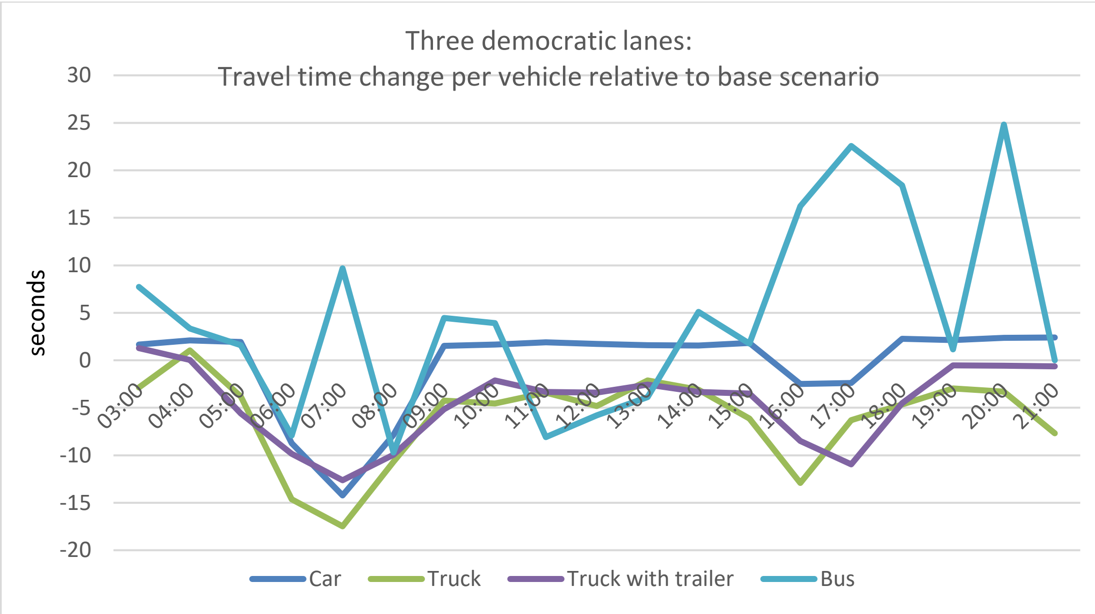

Figure 6: The time change in scenario 3.

5.4 100% trucks without trailers allowed to use the bus lane

It is possible that the bus lane could be used more efficient by letting fewer vehicles use the bus lanes. Ideally we should select the trucks into the bus lane (with trailer or not) that have the highest value of time. However, since there is no way to discriminate and select vehicles into the bus lane based on the value of time (since this is not known to an outsider), this cannot be done without some form a pricing of the bus lane. Applying a pricing measure automatically implies that only the trucks with high value of time use the bus lane – the others are not willing to pay the charge to reduce their travel time.

However, what can be done is to let only trucks without trailer use the bus lane. In this scenario we assume that only the trucks without trailers use the bus lane.

The effects on the travel time are show in Figure 7. It is clear that the buses now are slowed down in the morning peak. The passenger cars get lower travel in the peak (because some of the trucks that causes congestion in the morning peak are diverted to the bus lane). However, the buses are slowed down quite substantially, when they mix with the trucks. More than 90 percent of the trucks without trailer use the bus lane. There is a benefit of 1972, which is lower than all other policies.

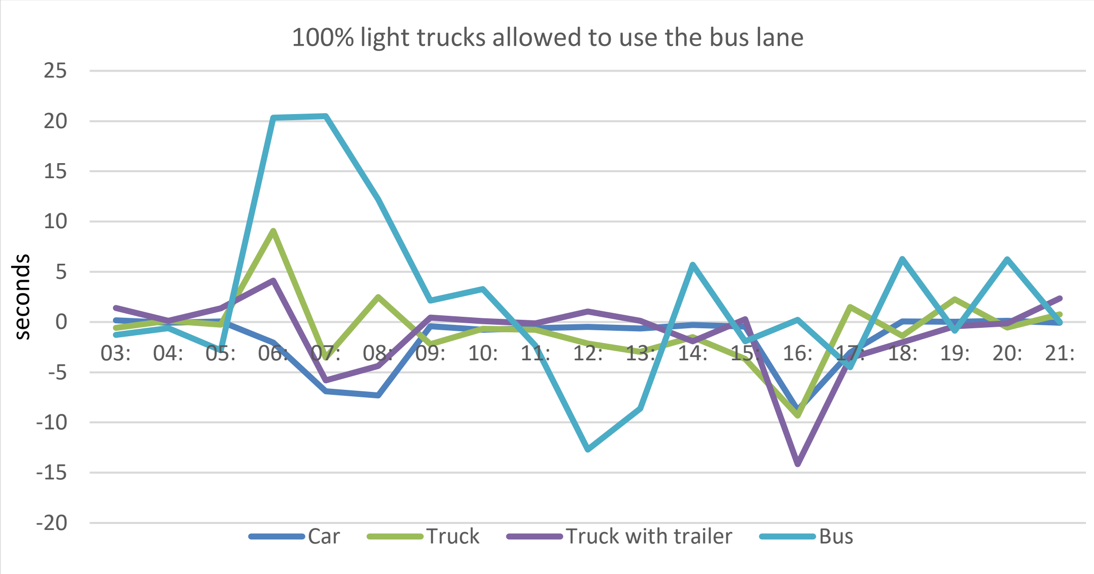

Figure 7: The time change in scenario 4.

5.5 100% trucks with trailers allowed to drive on the bus lane

In the final scenario we assume that 100% trucks without trailers are allowed to drive in the bus lane. This does barely slow down the buses at all, and the small travel time increase for the buses are more than compensated for by the large travel time reductions for the other types of traffic. Interestingly, the gain is large also for light trucks and passenger car. This is essentially because the mix of different traffic types reduces the capacity of the lane and slows down all traffic. The total net benefit is 4338 SEK/h. More than 90 percent of the trucks with trailer use the bus lane.

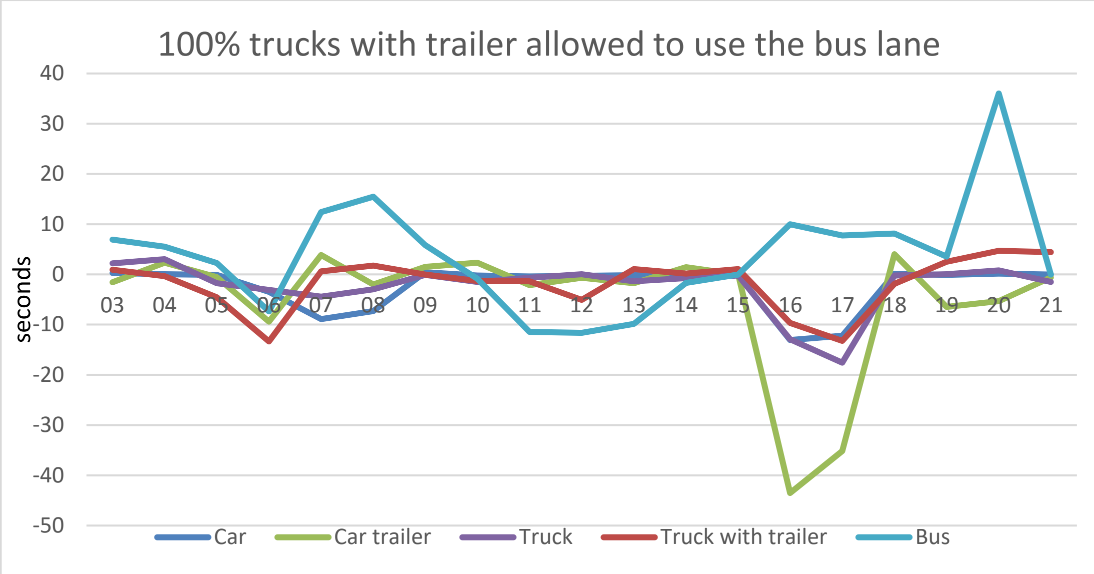

Figure 8: The time change in scenario 5.

5.6 Summary and conclusion

We can learn a number of things from the simulation and computation above. The first is that the benefit of letting trucks use the dedicated bus lane is positive, simply because there are not enough buses in the bus lane for the road space to be used as efficiently as possible in the present situation. This might not be the case in bus corridors with substantially more bus traffic, but this is probably transferable to many other corridors.

Second, since the congestion on the congestion on the road stretch is limited because congestion charges does already apply, it is most efficient to let all trucks use the bus lane. This might, however, not be the case in corridors with more congestion and more trucks. In those cases it might be most efficient to let only the heavy trucks use the bus lane. They do not slow the buses down so much, because they drive in the same speed. This is probably applicable to most corridors and even if congestion is substantially higher.

To summarize: Letting trucks use the bus lane would increase the benefit for society unless the number of buses is substantially higher. Unless the number of trucks is substantially higher, it is beneficial for society to allow them all to use the bus lane. If they volume of trucks is substantially higher, the most beneficial policy for the society is to allow trucks with trailers only in the bus lane, if not pricing measures can be applied to sort out the trucks with the highest value of time into the bus lane.

6 OTHER MEASSURES IMPORVING ACCESSIBILITY FOR DELIVERIES AND AIR QUALITY

As we saw in the previous section, the air quality did not improve local air quality letting the trucks use the dedicated bus lanes, simply because the number of trucks by time-of-day is constant. However, there are two other potentially effective ways of increasing the air quality by the prioritization of buses to the bus lanes. One is to allow only trucks with a high degree of filling to use the bus lane, or that only "clean trucks" can use the bus lanes. The efficiency of such measures will be discussed on section 6.1. Another possible way is to run distribution traffic during the night hours. This is discussed in section 6.2.

6.1 Air Quality in the long run

In Gothenburg and in other cities, there have been experiences with environmental zones. Commissioned by the city of Gothenburg, Ecotraffic ERD3 AB calculated and evaluated how the environmental zones in Göteborg introduced in 1996 affected the emissions of carbon dioxide (HC), carbon monoxide (CO), nitrogen oxides (NOX) and particles (PM) in 2004.

The effects of the environmental zones are the effects on NOx emissions. The total reduction of NOX emissions within the zone is over was 13 tonnes per year by the regulations - as a direct consequence of the environmental zone (Ecotraffic ERD, 2005). Particle emissions also decreased sharply (highest effect counted as percentage reduction).

A key problem with the effectiveness and the evaluation of the environmental zones, however, have been the enforcement –the authorities must monitor and penalize trucks that do not meet the regulations using the zones. Interviews with involved civil servants have seen profs of carries that used the zone illegally. A general conclusion from these works is therefore that to get the desired effect one needs to include some form of vehicle-dependent charges depending on the emission of the vehicle. However, this is politically difficult.

An effective measure would therefore be to instead of environmental zones adopt differentiated congestion taxes for heavy vehicles based on the truck's health damaging emissions. It would probably be much more efficient if the system it was national, increasing the incentive for carriers to invest in cleaner vehicles. This would be a complement to the congestion tax already implemented in Stockholm and Gothenburg

In 2012, the City of Gothenburg gave WSP the task of designing a proposal for environmental differentiation for heavy vehicles within the congestion tax system in Gothenburg, and assess the effects of the proposal. The purpose of introducing environmental differentiation would primarily be to improve the local environment in Gothenburg by giving companies incentives to drive with cleaner vehicles. An environmental differentiation may affect the firm's choice of vehicle and route choice in different ways: by increasing the speed of phasing out of older vehicles with more harmful emissions for human health, by reallocation of the fleet of vehicles, so that a company's older vehicles are allocated outside the congestion area, or by changing route choice (take a detour around the congestion tax area).

However, the impact of different alternative types of congestion tax on heavy vehicles would be very difficult to assess at present (WSP, 2012). There is no quantitative basis on how companies react to environmental differentiation in terms of vehicle ownership.

6.2 Night time deliveries

As part of the program "Off-Peak City Distribution" Sanchez-Diaz et al. (2016) review literature on shifting freight traffic to the off-peak hours: this has been a popular initiative considered for many years by both the private and the public sector, and there seems to be a consensus that there are benefits that these programs could bring about, e.g., travel time savings, fuel savings, environmental savings, and stakeholders' satisfaction. They also identified a number of challenges that need to be considered and addressed to ensure the success of peak hours distribution, such as decreasing noise impacts, relaxing access and loading/unloading restrictions, and ensuring stakeholder engagement. However, a handful of cities have identified key factors to overcome these challenges. In fact, shifting goods deliveries to less congested hours, when fewer people are exposed to the local emissions, has a very long history. It was implemented already in ancient Rome when Julius Caesar to reduce congestion (Dessau, 1902).