Foreword

Trafikverket conducted a trial entitled "Environmentally Adapted Speed on Road E18" in 2009-2010. The SLB Analysis Unit at the Environment and Health Administration in Stockholm had been tasked to conduct "Measurement and Evaluation of Air Quality along Road E18 between the Danderyd Hospital and Danderyd Church Interchanges".

The background to the project is that emission studies showed a clear correlation between vehicle speed and particulate emissions, but verification was lacking as to whether the correlation also applied to particulate levels in actual traffic environments. Trafikverket wanted to study whether high particulate levels could be counteracted by means of lower vehicle speed, and a stretch with the variable of speed was deemed to be a suitable study environment for the project. In addition to air quality, comprehensive analyses were performed with respect to the impact on noise and carbon dioxide emissions along the stretch.


This report is an English abridgement of Trafikverket's publication 2011:042 "Miljöanpassad hastighet på E18" (Environmentally Adapted Speed on E18), which presents the follow-up measurements and regression analyses performed along E18 Norrtäljevägen in winter and spring 2009/2010, as well as analyses and traffic & environmental data from Road 75 Södra länken Tunnel and Road E4/E20 Essingeleden. The report 2011:042 "Miljöanpassad hastighet på E18" (Environmentally Adapted Speed on E18), is available from Trafikverket's website http://www.trafikverket.se/Privat/I-ditt-lan/Stockholm/Miljoanpassad-hastighet/, where reports and experience that concern the project have been compiled.

Borlänge, June 2012

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1 Summary

The report describes the variation in levels of inhalable particles, $\text{PM}_{10}$, and nitrogen oxides ($\text{NO}_{x}$) at various measuring points along Road E18 Norrtäljevägen. The primary purpose of analysing the data was to identify correlations between vehicle speed and $\text{PM}_{10}$ levels, to be used in realtime to counteract high $\text{PM}_{10}$ levels by adjusting speed limits. Similar analyses were also performed on measurement data from Road 75 Södra länken and the measuring point adjacent to Road E4/E20 Essingeleden.

1.1 Measurement programme 2010 compared with 2009

Some key differences:

- Four measuring points were used instead of six
- Total traffic flow and total average speed past the measuring points were recorded (previously only limited data was available for northbound lanes)
- Studded tyre calculations were performed on site (none previously)
- Road surface moisture was measured (none previously)

1.2 Measurement results

The measurement programme in winter and spring 2009/2010 provided data from December 2009 to May 2010, which was used to analyse correlations between speed and $\text{PM}_{10}$ levels. The weather during the measurement period had a major impact on air pollution levels. Due to moist road surfaces as the result of constant snow cover from mid-December to mid-March, $\text{PM}_{10}$ levels were low throughout the period. Road surfaces dried starting in mid-March; $\text{PM}_{10}$ levels rose and were high from the second half of March until May. Because of the severe winter, stable weather conditions were predominant in December-March and $\text{NO}_{2}$ levels were high, after which they declined significantly when the snow began to melt in mid-March.

The environmental quality standard for average daily value was exceeded for both $\text{PM}_{10}$ and $\text{NO}_{2}$ in 2009 and 2010 alike. In other words, during the measurement period (approximately six months), there were more days with levels above the limits than the standard permits for an entire calendar year.

1.3 Correlation between vehicle speed and contribution of traffic to particulate levels

An analysis of the measurements from E18, Essingeleden and Södra länken Tunnel, shows that vehicle flow is the single most important factor that affects $\text{PM}_{10}$ levels. To calculate the impact of reduced speed on $\text{PM}_{10}$ levels, the ratio of $\text{PM}_{10}$ levels to $\text{NO}_{x}$ was used. The analysis shows that the emission factors for E18, Essingeleden and Södra länken Tunnel are the same within a 95 per cent confidence interval, which confirms that the correlations are reliable.

1.4 What impact can environmentally adjusted speed have on total $\text{PM}_{10}$ levels?

The emission factor arrived at for E18 was used to calculate the possible impact of various speed reductions on $\text{PM}_{10}$ levels. The analysis shows that if the average daytime (6 am to 6 pm) speed were reduced by 5 km/hour, the average daily values of $\text{PM}_{10}$ would decline such

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1 Quantity of particles with a diameter less than 10 micrometres
2 Total level of $\text{NO}$ and $\text{NO}_{2}$
3 Stepwise multiple linear regression
that the number of days with levels above 50 µg/m³ would decrease from 49 to 45. More than 35 days (the limit according to the standard) per year would still have levels above 50 µg/m³. Average speed would have to be reduced by more than 20 km/hour to meet the standard. The impact of speed reduction on the number of days with levels above 50 µg/m³ is highly dependent on meteorological conditions in the spring when PM₁₀ levels are highest. Speed reduction lowers emissions and concentrations and thereby reduces negative health effects due to road dust exposures.

1.5 Global warming and noise
Traffic has a significant impact on global warming, primarily through carbon dioxide emissions. The transport sector is to contribute to the attainment of the environmental quality objective of Reduced Climate impact; particularly on roads with speed limits above 70 km/hour, lower speeds significantly reduce the carbon footprint by cutting down on fuel consumption.

In the case of Road E18 through Danderyd, a speed reduction of 10-12 km/hour would lower carbon dioxide emissions by an estimated 5-10 per cent. Reducing speeds by that amount would make a contribution of approximately 25 per cent towards meeting Trafikverket Region Stockholm’s target for total emission reductions in 2010 and 2011.

Along the most heavily trafficked roads, there is a risk of noise exposure that exceeds the Riksdag’s target value (55 dBA), even though anti-noise measures have been taken in the most exposed points.

For Road E18 through Danderyd, noise emissions from traffic could decline by 1.5-2 dBA and approximately 160 additional households (approximately 400 residents) would fall below the target value if the northbound speed limit were observed and actual southbound speed were lowered by 10-15 km/hour. The measure accounts for one-tenth of Trafikverket’s regional target until 2020.

1.6 Discussion
Emission factors for PM₁₀ have been calculated on the basis of regression coefficients for the ratios of PM₁₀ levels to NOₓ levels based on measurements alongside Roads E18 and Essingeleden, as well as in Södra länken Tunnel in Stockholm. The factors turn out to be of approximately equal size and significant at each of these measuring points. Speed reduction would lower PM₁₀ levels, but additional measures are needed to meet the environmental quality standards.

PM₁₀ emissions are due primarily to wear and tear on the road surface by studded winter tyres. The results in this report are fully in line with laboratory studies, road tunnel studies and measurements with mobile laboratories in Sweden and Finland, which demonstrate that studded tyres aggravate road surface wear and tear when vehicle speeds increase.

The speed correlations in this study refer to motorways and approach roads. Studies indicate that speed reduction along other types of roads, such as central city streets, also lower particulate emissions, albeit not as much at slower speeds.

Speed affects not only coarse particles that generate wear and tear, but ultrafine particles and gases that are emitted through exhaust fumes. Speed reduction can be expected to alleviate the health effects of particulate emissions; however, studies suggest that there is no threshold under which the health risk is zero, and all measures that reduce emissions deserve consideration.
1.7 Conclusions

- The factors turn out to be of approximately equal size and significance for all three stretches that were measured, which confirms that the correlations are reliable.
- The average emission factor in 2009-2010 was $68 \pm 8 \text{ mg}$.
- PM$_{10}$ per vehicle kilometer per 10 km/hour change in vehicle speed. If average speed during the day (6 am to 6 pm) were reduced by 5, 10 or 20 km/hour, there would be 4, 8 or 12 fewer days respectively with levels above the $50 \mu g/m^3$ limit.
- For the number of days with levels above $50 \mu g/m^3$ to decrease from 49 during the measurement period to fewer than 35 (environmental quality standard), average speed would have to be reduced by somewhat more than 20 km/hour (assuming that speed was the only tool used to change pollution levels).
- Speed reduction also lowers the average level of particulate contaminants – an average reduction of 10 km/hour would lower the level by approximately 13 per cent.
- CO$_2$ emissions from traffic could decrease by approximately 7 per cent if the average speed (for purposes of calculation) were reduced by 10 km/hour on the E18 stretch through Danderyd (approximately 2.8 km), which corresponds to approximately 25 per cent of Trafikverket Region Stockholm’s contribution in 2010 and 2011 towards attainment of the climate targets for Sweden set by the Government and Riksdag.
- The daily equivalent noise level target of 55 dBA is exceeded for an estimated 700 households. If average speed were reduced by 10-15 km/hour, the decrease in noise level would be approximately 1.5-2 dBA and approximately 160 more households (approximately 400 residents) would meet the 55 dBA target.
2 Introduction

Along the most heavily trafficked roads in Stockholm County and in central Stockholm, particulate levels exceed the standards set by the EU directive and Swedish legislation on air quality. A study found that a number of schools and preschools in the county are located in areas where levels are above or close to the standards (http://slb.nu/exponering/). Besides trying to reduce traffic volumes and the percentage of studded winter tyres, very few measures effectively lower particulate levels. One measure with some potential is to reduce speed on the roads. Since autumn 2007, Trafikverket has had signs with variable speed limits along E18 southbound between Viggbyholm and Danderyd Hospital. The purpose of adjustable speed limit signs is to minimise queues and the risk of collisions when traffic is heavy. On behalf of Vägverket, SLB Analysis previously assessed differences in air pollution levels along this stretch at speeds of 70, 90 and 110 km/hour. The calculations showed that a reduction in average speed from 90 to 70 km/hour could enable the stretch to meet the environmental quality standard for PM$_{10}$ (LVF 2008:15). The calculations are associated with fairly high uncertainty because the correlations between speed and emissions of particles that generate wear and tear have not previously been quantified for conditions in Stockholm. PM$_{10}$ levels need to be measured along the stretch in order to shed more light on the correlation.

The primary purpose of the project was to identify correlations between vehicle speed and PM$_{10}$ levels, to be used in realtime to counteract high PM$_{10}$ levels by adjusting speed limits. The first report, "Mätningar av luftkvalitet vid väg E18 mellan trafikplatserna Danderyd sjukhus och Danderyds kyrka" (Measurements of Air Quality along Road E18 between the Danderyd Hospital and Danderyd Church interchanges) presented the measuring points, measuring methods and background to the project (SLB 6:2009). This, the second report, presents an analysis of the measurement results for 2009 (SLB 7:2009). The comprehensive progress report 2011:042 "Environmentally Adapted Speed on E18" presents results and analyses of the measurements that were performed along E18 at Mörby in winter and spring 2009/2010. Corresponding analyses of measurement data from Road 75 Södra länken and Road E4/E20 Essingeleden are also presented. This report is an English abridgement of Trafikverket’s publication 2011:042 “Miljöanpassad hastighet på E18” (Environmentally Adapted Speed on E18).

3 Trial stretch and equipment along E18

3.1 Air pollution measurement

The trial stretch is north and southbound Road E18 from the Danderyd Hospital to Danderyd Church interchanges (Figure 1).

The trial equipment consists of four measuring points located in pairs in two sections on either side (east and west) of Road E18

a) north of Kyrkogårdsvägen with instruments for measuring PM$_{10}$ (the mass of all particles with an aerodynamic diameter < 10µm), nitrogen oxides NOx (sum of nitrogen monoxide, NO, and nitrogen dioxide, NO$_2$) for 15-minute averages on both sides of the road, as well as meteorology on the east side. The measuring points are designated as NV for the west side and NO for the east side of the road.

b) north of the footpath under Road E18’s northern interchange at Danderyd Hospital with instruments for measuring PM$_{10}$ levels and size distribution for the coarse particle fraction (5-minute average) on both sides of the road, as well as meteorology on the west side. The measuring points are designated as SV for the west side and SO for the east side of the road.
The measuring points are described in greater detail in SLB Report 6:2009, with the difference that the points adjacent to Mörby Centre were not used in winter and spring 2009/2010.

3.2 Meteorology
For the 2009/2010 trials, the measuring point on the west side of Danderyd Hospital was supplemented with a point for measuring wind speed, wind direction, temperature and relative humidity. The point started up in January 2010. The same type of measurement equipment that was described in SLB Report 6:2009 for the point at Danderyd Hospital was used. Figure 1 shows the locations of the measuring points.

3.3 Road moisture
Sensors were installed in spring 2010 to monitor road surface moisture at the measuring points on the west side by Danderyd Church. Due to the protracted snow cover during the winter, the sensors could not be installed until 30 March. The sensors were up and running and fully functional until 20 April, after which they showed clear signs of no longer providing reliable data.

3.4 Measuring traffic
Trafikverket recorded traffic flow and vehicle speed at two locations adjacent to the measuring points for air pollution parameters. Traffic flow and vehicle speed were recorded by microwave detectors, which measure traffic in all north and southbound lanes past the measuring point. The following parameters were recorded:

1. Number of vehicles:
   - 0-6 m Cars, motorcycles
   - 6-12.5 m Lorries, minibuses, buses
   - 12.5-24 m Articulated buses, lorries with trailers

2. Average speed for all vehicles

Figure 1 shows the location of equipment for measuring traffic.
Figure 1. Points for measuring traffic and speed are indicated with blue lines and points for measuring particulate levels are indicated with red dots.

4 Measurement from Södra länken and Essingeleden

Measurement data from Södra länken road tunnel and Essingeleden (highway) have been used as supplementary information to study the impact of vehicle speed on generation of PM$_{10}$. 
5 Results

A large quantity of measurement data were collected. For all the data, see Trafikverket’s publication 2011:042 ”Miljöanpassad hastighet på E18” (Environmentally Adapted Speed on E18), as well as its appendices and references [http://www.trafikverket.se/Privat/I-ditt-lan/Stockholm/Miljoanpassad-hastighet/](http://www.trafikverket.se/Privat/I-ditt-lan/Stockholm/Miljoanpassad-hastighet/)

Examples of measurement data are presented below to shed light on key considerations when analysing them.

5.1 Variation in traffic flow and vehicle speed

At times (particularly during morning rush hour), there are major differences between north and southbound traffic, and even between various lanes in the same direction. But all analyses in this report are based on total traffic flow and total average speed, given that air pollution levels are affected more or less the same by north and southbound traffic. Thus, the diagrams below present only total traffic flow and total average speed for all vehicles past the measuring points.

Figure 2 shows variations in the total flow of both north and southbound traffic from November 2009 to May 2010. On each occasion, the flow was greater past Danderyd Church than Danderyd Hospital. The reason is that some southbound vehicles use the exits towards Mörby Centre and Danderyd Hospital. Traffic flow was significantly less during Christmas. It was even less from 14 December to 20 March when Stockholm was under constant snow cover. The heaviest traffic flow was recorded in early May.

![Traffic flow E18](image)

**Figure 2.** Total traffic flow per day past the measuring points at Danderyd Church and Danderyd Hospital
As an example, Figure 3 shows the variation of traffic flow and vehicle speed on weekdays past the southern measuring points. The results were essentially the same for the northern points. Speed was somewhat lower in March than April and May. As was the case for the northern points, traffic flow was also somewhat less in March.

Figure 3. Variation in traffic flow and vehicle speed past Danderyd Hospital on weekdays from March to May 2010
Figure 4 shows the percentage of time at various average speeds on E18 from 1 November to 31 May. The most common speed was 85-90 km/hour at both points. However, speeds above 90 km/hour were more common at Danderyd Church than Danderyd Hospital. Speeds below 85 km/hour were more common at the southern measuring point.

Figure 4. Percentage of time at various average speeds at the two cross-sections of E18 from 1 November 2009 to 31 May 2010

5.2 Meteorology and road surface moisture

Winter and spring 2009/2010 were unusually cold and snowy in the Stockholm area. Heavy snowfall on 14 December left a cover that was replenished throughout the winter and didn’t disappear until late March. Average monthly temperatures from December 2009 to March 2010 were lower than the multi-year average, as well as the same period of 2008-2009.

Average precipitation during the measurement period was less than previous years for most months, as well as the previous year for November, December and March. The difference was that all the precipitation this time was snow. Thus, despite the smaller quantity of precipitation, the low temperatures ensured a constant snow cover from mid-December until late March.

One consequence of the protracted snow cover was that the road surfaces were mostly moist (or partly icy/frozen) throughout much of the measurement period. Figure 5 shows the percentage of hours when the surface of Sveavägen in central Stockholm was moist during the measurement period compared with the previous year. Only in November was it drier for more hours in 2009/2010. A dry surface was not measured for a single hour in January and February and for only a small percentage of the time in December and March. Road moisture has a major impact on PM_{10} levels, since dust is suspended first and foremost when the surface is dry. There were long intervals during the measurement period that provided poor conditions for observing road dust.
Figure 5. Percentage of hours when the surface of Sveavägen was dry in winter and spring 2009/2010 compared with 2008/2009

Measurements were performed on both sides of E18 to determine the contribution of traffic to air pollution levels depending on the direction of the wind. The distribution of wind direction showed relatively large variations from month to month. West and south-west winds were predominant in March. South winds were predominant in April and east and north-east winds in May. Such large variations had a significant impact on both PM$_{10}$ and NO$_x$ levels.

5.3 Use of studded tyres

A large percentage of PM$_{10}$ emissions from road traffic are the result of wear and tear caused by studded tyres, which has been demonstrated in pavement testing machines (VTI Report 520:2005), with mobile measurements (Hussein et al., 2008; ITM Report 172:2007), and at fixed measuring points (SLB Report 4:2004, SLB Report 2:2008).

Figure 6 shows the percentage of cars that used studded tyres during the measurement period. The data were recorded manually using the difference in sound during passage of a vehicle with studded tyres compared to a vehicle without studded tyres. Approximately 200 vehicles were recorded on each occasion. The diagram contains data from E18, Ekerövägen and Sveavägen in central Stockholm. The recorded percentage of vehicles with studded tyres was generally higher on E18 than central Stockholm but usually lower than Ekerövägen. The results also show large variations between the various measurements on E18. The temporal variations at a particular site are more a reflection of the particular observations and uncertainties associated with the measurement method itself. Presumably the percentage of vehicles with studded tyres varies throughout the day as well. The weather was relatively mild in early autumn and use of studded tyres increased very slowly. The decline in their use during the spring was relatively rapid. One reason was no doubt the new regulations as of 2010 that outlawed the use of studded tyres after 15 April (previously 30 April).
5.4 Air pollution levels

Road surface moisture has a very large impact on PM$_{10}$ levels. Elevated levels were measured only on occasional days before mid-March. Once the snow began to melt and the road surfaces dried, PM$_{10}$ levels rose and were elevated on most days between 10 March and 31 May. Due to moist road surfaces in early 2010, PM$_{10}$ levels along E18 and at all other measuring points in the Stockholm area were low from January to mid-March.

NO$_x$ levels (Figure 7) varied differently than PM$_{10}$ levels during the measurement period. NO$_x$ comes from exhaust fumes and is not affected by road surface moisture.

Environmental quality standards apply to NO$_2$, but NO$_x$ is a better tracer of pollutants from vehicle exhaust. Levels were generally high from December to February, with the exception of the Christmas holidays. Low temperatures during the winter often led to stable weather conditions and temperature inversions in the morning and afternoon. The result was elevated levels. NO$_x$ levels were higher on the west side, whereas PM$_{10}$ levels were usually higher on the east side. Heavy vehicles make a relatively large contribution to NO$_x$ emissions; given that they were often in the lane closest to the measurement sampling point, they had that much more of an impact on pollution levels. PM$_{10}$ emissions come primarily from road surface wear and tear caused by studded tyres. Studded tyres are almost always on cars, which travel in all lanes; as a result, PM$_{10}$ emissions may become more diluted before they reach the sampling point.
Figure 7. Average daily NOx levels for the measuring points at Danderyd Church

Average variations on weekdays are presented as a means of comparing the concentrations at various measuring points, as well as comparing concentrations with traffic flow. Measurement data are available with 15-minute time resolution but are presented in the diagram below only as hourly mean values. Figure 8 shows PM10 levels at Danderyd Church on the west side of the road on weekdays, broken down by month.
Figure 8 clearly demonstrates that the highest levels at point NV were measured in April and the lowest in February. The reason is the variation in road surface moisture (see Section 5.2). The month-to-month variations were different on the east and west side of the road. The explanation can be found in wind direction. Due to the large percentage of west winds in March, levels were significantly higher on the east side of E18 (see Section 5.2). High levels were measured in May 2010 even though only a small percentage of vehicles used studded tyres. The main reason is presumably that the particles that formed during the long winter with its moist road surfaces remained by the road and were suspended to air in late April and May.
Weekday variations of NO\textsubscript{x} exhibit a somewhat different pattern than PM\textsubscript{10} levels. Figure 9 shows that levels are approximately the same during morning rush hour, but that large differences arise later in the day between the lower levels in March-May and the higher levels in December-February. Once spring arrives, the weather becomes more turbulent and windy during the afternoon, as opposed to winter when stable conditions can remain for the entire day. The small percentage of east winds in May 2010 was also reflected in low NO\textsubscript{x} levels on the west side.

5.5 Summary of the measurements
The measurement programme in winter 2009 and spring 2010 along E18 in Danderyd generated a large quantity of data. The two measuring points adjacent to Danderyd Church provided data of satisfactory quality from December 2009 to May 2010. Complete data were also collected by Trafikverket during the same period, and data from these points formed much of the basis for the correlations between vehicle speed and PM\textsubscript{10} levels presented in this report. The two measuring points at Danderyd Church provided data of good quality only in April and May 2010, so that correlations between speed and PM\textsubscript{10} levels could be processed only for that period.

Winter 2009/2010 featured a great deal of snow, which probably affected PM\textsubscript{10} levels. The cold and snowy period from mid-December to mid-March kept road surfaces moist, which contributed to low PM\textsubscript{10} levels the entire time. Road surfaces dried in mid-March and PM\textsubscript{10} levels rose substantially, remaining high for the rest of the measurement period. A probable reason for high levels in May as well is that many particles that formed due to wear and tear caused by studded tyres were not carried away during the period of moist road surfaces. When the road surfaces finally dried, the levels were high due to the suspension of accumulated particles. With respect to both monthly averages and the number of days above 50 µg/m\textsuperscript{3}, PM\textsubscript{10} levels were generally somewhat lower in March-May 2010 than the same period of 2009 (SLB Report 7:2009). NO\textsubscript{2} levels were elevated from December 2009 to February 2010. Stable weather conditions and snow cover during the period caused high NO\textsubscript{2}...
levels, which declined significantly when the snow started to melt in mid-March. NO₂ levels were significantly higher in March 2010 than March 2009 (SLB Report 7:2009), but approximately the same in April-May of both years.

Measurements showed that daily levels of both PM₁₀ and NO₂ exceeded environmental quality standards. This was the second consecutive year that measurements along E18 showed that levels exceeded the standards.

Traffic flow and vehicle speed exhibited variations on weekdays, with the flow clearly peaking during the morning and afternoon rush hour. In addition, speed significantly decreased during the morning rush hour. The same was true of the afternoon, though not to the same extent. Both speed and traffic flow were somewhat lower at Danderyd Hospital than Danderyd Church. With a few exceptions, average speed varied from 70 to 90 km/hour.

PM₁₀ and NOₓ levels varied greatly from month to month, primarily due to weather conditions and use of studded tyres. However, both PM₁₀ and NOₓ levels followed the same pattern as traffic flow, i.e., highest during the morning rush hour, for each month with measurement data. Poorer air mixing in the morning led to significantly higher levels during morning rush hour than the afternoon. Covariance between air pollution levels and traffic flow clearly demonstrates that the traffic on E18 was the greatest source of contaminants at the measuring points (SLB Report 7:2009).
6 Overview of emission factors in relation to vehicle speed

To compare speed correlations for E18, Essingeleden and Södra länken, emission factors were calculated by multiplying the regression coefficients\(^4\) for \(\Delta\text{PM}_{10}/\Delta\text{NO}_x\) (g PM\(_{10}\)/g NO\(_x\)) by the emission factor for NO\(_x\) (g per vehicle kilometre; g/vkm). The emission factors NO\(_x\) depend primarily on vehicle age and composition, as well as speed to a certain extent.

Table 1 and Figure 10 present estimated emission factors for PM\(_{10}\) from the measurements along E18, Essingeleden and Södra länken. Most of the levels did not differ significantly (i.e., the 95 per cent confidence intervals overlap). The average for E18 was 79 mg PM\(_{10}\)/vkm per 10 km/hour. Disregarding 2007 (when dust alleviation was performed), emission factors tended to decline along Essingeleden in 2006-2010, although the differences between the years are not statistically significant. Whether there was a declining trend in the quantity of PM\(_{10}\) emissions cannot be determined, however, given that the emission factor for NO\(_x\) decreased substantially during the period. The average for all measurements in 2009-2010 was 68 ± 8.4 mg PM\(_{10}\)/vkm per 10 km/hour.

\(^4\) To read more about the regression analysis, see Trafikverket’s publication 2011:042 “Miljöanpassad hastighet på E18” (Environmentally Adapted Speed on E18), [http://www.trafikverket.se/Privat/I-ditt-lan/Stockholm/Miljoanpassad-hastighet/](http://www.trafikverket.se/Privat/I-ditt-lan/Stockholm/Miljoanpassad-hastighet/)
Table 1. Emission factors for PM$_{10}$ depending on speed, calculated from regression coefficients$^5$.

<table>
<thead>
<tr>
<th>Point</th>
<th>Period</th>
<th>Emission factor used for NO$_x$ (g NO$_x$/vkm)</th>
<th>Emission factor ± 95 per cent confidence interval (mg PM$_{10}$/vkm per 10 km/h)</th>
</tr>
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<tbody>
<tr>
<td>E18 Northern measuring point</td>
<td>Dec 2009 – May 2010</td>
<td>0.70</td>
<td>79 ± 40</td>
</tr>
<tr>
<td>Essingeleden</td>
<td>Dec 2006</td>
<td>1.0</td>
<td>102 ± 70</td>
</tr>
<tr>
<td>Essingeleden</td>
<td>Jan – May, Dec 2007</td>
<td>0.88</td>
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<tr>
<td>Essingeleden</td>
<td>Jan – May, Dec 2008</td>
<td>0.75</td>
<td>87 ± 15</td>
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<tr>
<td>Essingeleden</td>
<td>Jan – May, Dec 2009</td>
<td>0.69</td>
<td>76 ± 12</td>
</tr>
<tr>
<td>Essingeleden</td>
<td>Jan – May, Dec 2010</td>
<td>0.62</td>
<td>65 ± 16</td>
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<tr>
<td>Essingeleden 2006 – 2010</td>
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<td>0.77</td>
<td>75 ± 7</td>
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<td>Södra länken eastbound</td>
<td>Jan – Apr 2009</td>
<td>0.70</td>
<td>70 ± 20</td>
</tr>
<tr>
<td>Södra länken westbound</td>
<td>Jan – Apr 2009</td>
<td>0.70</td>
<td>54 ± 10</td>
</tr>
<tr>
<td>Average (all data, 2009-2010)</td>
<td></td>
<td>-</td>
<td>68 ± 8.4</td>
</tr>
</tbody>
</table>

$^5$ To read more about the regression analysis, see Trafikverket’s publication 2011:042 "Miljöanpassad hastighet på E18" (Environmentally Adapted Speed on E18), [http://www.trafikverket.se/Privat/l-ditt-lan/Stockholm/Miljoanpassad-hastighet/](http://www.trafikverket.se/Privat/l-ditt-lan/Stockholm/Miljoanpassad-hastighet/)
7 What impact can environmentally adapted speed have on PM$_{10}$ levels?

The purpose of this section is to estimate the impact of hypothetical speed reductions on PM$_{10}$ emissions and PM$_{10}$ levels at the measuring point by Kyrkskolan along E18. The speed correlation for E18 was applied to the measurements performed in December 2009 – May 2010. The impact on average daily values and average values for the period (since the standards refer to daily values and average annual values) is presented below.

**Figure 10.** Emission factors for PM$_{10}$ depending on speed (same data as in Table 1).
Figure 11. Estimated impact of vehicle speed on the 60 highest average daily values of PM$_{10}$ levels along E18 (northern measuring point) in December 2009 – May 2010. The value “without a change in speed” refers to the highest measured level (the lee side of the road). The other lines show what the level could have been if average speed during the day (6 am to 6 pm) had been 2, 5, 10 and 20 km/hour lower than at the time of measurement.

The conditions refer to the measurement period. The impact of speed reduction on the number of values that exceed the standard depends on how the total levels are distributed, i.e., how many values are just above 50 µg/m$^3$. 
Table 2. Estimated impact of vehicle speed on the number of average daily values above 50 µg/m$^3$ and average value of PM$_{10}$ levels for the period along E18 (northern measuring point, Kyrkskolan) due to hypothetical reduction of average speed during the day (6 am to 6 pm). The value “without a change in speed” refers to the highest measured level (the lee side of the road). The PM$_{10}$ values without a change in speed are obtained from measurements over 5 months (December 2009 - April 2010).

<table>
<thead>
<tr>
<th>PM$_{10}$ without a change in speed</th>
<th>PM$_{10}$ with 2 km/h speed reduction</th>
<th>PM$_{10}$ with 5 km/h speed reduction</th>
<th>PM$_{10}$ with 10 km/h speed reduction</th>
<th>PM$_{10}$ with 20 km/h speed reduction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of average daily values &gt; 50 µg/m$^3$</td>
<td>49</td>
<td>49</td>
<td>45</td>
<td>41</td>
</tr>
<tr>
<td>Number of fewer days &gt;50 µg/m$^3$ at lower speed</td>
<td>0</td>
<td>4</td>
<td>8</td>
<td>12</td>
</tr>
<tr>
<td>Average value (µg/m$^3$) for the period</td>
<td>41</td>
<td>39</td>
<td>37</td>
<td>36</td>
</tr>
<tr>
<td>Decrease in average value at lower average speed</td>
<td>-4 %</td>
<td>-8 %</td>
<td>-13 %</td>
<td>-18 %</td>
</tr>
</tbody>
</table>

Table 2 shows that a reduction of average speed by 2, 5, 10 and 20 km/hour during the day (6 am to 6 pm) would lead to 0, 4, 8, and 12 fewer days respectively with levels above 50 µg/m$^3$. To bring the number of days with levels above 50 µg/m$^3$ below 35 (according to the environmental quality standard), average speed would have to be reduced by more than 20 km/hour under the conditions that prevailed from December 2009 to May 2010. In other years the same speed reduction can lead to more (or fewer) days with levels above (or below) the standard depending on the total levels, which are mostly affected by local conditions such as road surface moisture and weather (stability and wind speed), as well other sources and particles carried in from other countries. The table also shows that average levels decrease by 4-18 per cent with a speed reduction of 2-20 km/hour.

8 Carbon dioxide emissions along E18 through Danderyd

8.1 Background

There is a risk along the most heavily trafficked roads in Stockholm County that the exposure of residents to particles and nitrogen oxides will exceed environmental standards. Traffic also has a considerable impact on global warming, primarily through carbon dioxide emissions. The transport sector is to contribute to attainment of the environmental quality objective of Reduced Climate impact as follows:

/.../ by incremental increases in the energy efficiency of the transport system and by breaking dependency on fossil fuels. By 2030 no vehicles in Sweden should be dependent on fossil fuels.

A number of parallel measures are required for the transport sector to contribute to attainment of the climate targets. A key factor is vehicle speed, both lower speed limits and increased compliance. Speed, particularly on roads with speed limits above 70 km/hour, significantly increases the carbon footprint due to higher fuel consumption and carbon
dioxide emissions. Reduced speed on a major European road like E18 can make a considerable contribution to attainment of the climate targets.

Variable speed limits can also reduce emissions by virtue of less queue formation. However, Trafikverket has no model for such calculations.

8.2 Previous studies

Trafikverket has put together an informational and strategy document on the implications of climate targets for the transport sector, its potential for contributing to their attainment and priority measures. Entitled *Trafikslagsövergripande planeringsunderlag för begränsad klimatpåverkan (Multi modal decision basis for climate mitigation in planning)*, the document is to serve a coordinating function for Trafikverket’s efforts in the area. The document contains a discussion of the potential of lower speed limits in the road network, as well as compliance with existing limits.

8.3 Calculation method

As mentioned at the beginning of this report, fuel consumption and CO₂ emissions are directly linked to speed. On straight highways and motorways, the greater the speed over 70 km/hour, the higher the fuel consumption and emission levels. See diagram below:

![Figure 12: Carbon dioxide emissions and fuel consumption of cars at various speeds](image)

The project’s calculations are based on carbon dioxide emissions (g/km) at various speed from cars, lorries without trailers and lorries with trailers. The emissions are calculated on the assumption of a straight highway, including speed variations and stops. However the

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6 Publication 2010:095, is available at [www.trafikverket.se](http://www.trafikverket.se)
measurements do not consider driving patterns, which can considerably affect fuel consumption. Efficient driving, for example, can lower fuel consumption by 10 per cent.7

8.4 Traffic 2010
Since 2009, traffic on E18 through Mörby has been measured in two segments – north of Danderyd Hospital and south of Danderyd Church (Mörby). Total traffic flow in 2010 averaged approximately 68,000 vehicles per day, a decrease of approximately 4,000 since 20058.

Cars (vehicles shorter than 6 metres) account for approximately 90 per cent of the traffic.

8 The traffic figures for 2005 are probably somewhat of an overestimate (Ramböll), and construction of Norrotsleden has provided some relief for Road E18.
8.5 Some calculations

Calculations are performed for Road E18 between the Inverness and Danderyd Church interchanges, a 2.8 km stretch with separate measurements of north and southbound traffic.

Southbound traffic has variable speed limits, while northbound traffic has fixed speed limits. Emission calculations are performed for the measured speed, for speed reduction of 5 and 10 km/hour, and for the speed limit (see Table 3). Table 4 shows carbon dioxide emissions based on data in Table 3.

Table 3: Basic data for the stretch; 10 per cent heavy vehicles.

<table>
<thead>
<tr>
<th>Stretch</th>
<th>Length (m)</th>
<th>Flow (vehicles/day)</th>
<th>Actual speed (km/hour)</th>
<th>5 km/hour</th>
<th>10 km/hour</th>
<th>Speed limit/average speed (^9) (km/hour)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Stretch 1 southbound</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Interchange 180 Danderyd Church – Interchange 179 Mörby</td>
<td>1,200</td>
<td>34,000</td>
<td>93</td>
<td>88</td>
<td>83</td>
<td>93</td>
</tr>
<tr>
<td><strong>Stretch 1 northbound</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Interchange 180 Danderyd Church – Interchange 179 Mörby</td>
<td>1,200</td>
<td>34,000</td>
<td>88</td>
<td>83</td>
<td>78</td>
<td>90</td>
</tr>
<tr>
<td><strong>Stretch 2 southbound</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Interchange 179 Mörby – Interchange 178 Danderyd Hospital</td>
<td>900</td>
<td>32,000</td>
<td>88</td>
<td>83</td>
<td>78</td>
<td>88</td>
</tr>
<tr>
<td><strong>Stretch 2 northbound</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Interchange 179 Mörby – Interchange 178 Danderyd Hospital</td>
<td>900</td>
<td>32,000</td>
<td>82</td>
<td>77</td>
<td>72</td>
<td>70</td>
</tr>
<tr>
<td><strong>Stretch 3 southbound</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Interchange 178 Danderyd Hospital – Interchange 177 Iverness</td>
<td>700</td>
<td>34,000</td>
<td>88</td>
<td>83</td>
<td>78</td>
<td>[D3] 88</td>
</tr>
<tr>
<td><strong>Stretch 3 northbound</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Interchange 178 Danderyd Hospital – Interchange 177 Iverness</td>
<td>700</td>
<td>32,000</td>
<td>82</td>
<td>77</td>
<td>72</td>
<td>70</td>
</tr>
</tbody>
</table>

\(^9\) Actual average speed, which is lower than the speed limit, is used for southbound traffic.
**Table 4:** Impact on carbon dioxide emissions of speed reduction in accordance with Table 3

<table>
<thead>
<tr>
<th>Stretch</th>
<th>CO₂ emissions, tonnes per year</th>
<th>Actual speed</th>
<th>Change at actual speed - 5 km/hour</th>
<th>Change at actual speed -10 km/hour</th>
<th>Change at speed limit&lt;sup&gt;10&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interchange 180 Danderyd Church – Interchange 179 Mörby (South)</td>
<td>3,112</td>
<td>-138</td>
<td>-268</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Interchange 180 Danderyd Church – Interchange 179 Mörby (North)</td>
<td>2,974</td>
<td>-130</td>
<td>-231</td>
<td>+52</td>
<td></td>
</tr>
<tr>
<td>Interchange 179 Mörby – Interchange 178 Danderyd Hospital (South)</td>
<td>2,099</td>
<td>-92</td>
<td>-163</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Interchange 179 Mörby – Interchange 178 Danderyd Hospital (North)</td>
<td>1,989</td>
<td>-64</td>
<td>-118</td>
<td>-144</td>
<td></td>
</tr>
<tr>
<td>Interchange 178 Danderyd Hospital – Interchange 177 Iverness (South)</td>
<td>1,633</td>
<td>-71</td>
<td>-127</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Interchange 178 Danderyd Hospital – Interchange 177 Iverness (North)</td>
<td>1,547</td>
<td>-50</td>
<td>-92</td>
<td>-112</td>
<td></td>
</tr>
<tr>
<td><strong>Total (tonnes per year)</strong></td>
<td><strong>13,355</strong></td>
<td><strong>-545</strong></td>
<td><strong>-998</strong></td>
<td><strong>-204</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Percentage change</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>-4%</strong></td>
<td></td>
<td><strong>-7%</strong></td>
<td><strong>-2%</strong></td>
<td></td>
</tr>
</tbody>
</table>

<sup>10</sup> Actual average speed, which is lower than the speed limit, is used for southbound traffic.
8.6 Conclusions

Reduced speed lowers fuel consumption and thereby carbon dioxide emissions. Even on short stretches as in this project, speed reduction has been shown to considerably lower carbon dioxide emissions.

For the current project on Road E18, carbon dioxide emissions were lowered by 4-10% depending on the stretch and the estimated or actual speed reduction. However the figures are highly uncertain because several of the parameters are based on estimates.

Based on the decision of the Government and Riksdag that carbon dioxide emissions must decrease by 40 per cent by 2020 and 80 per cent by 2030 in order to meet the 2 degree target, Trafikverket’s total contribution in 2010 was calculated to be a reduction of 90,000 tonnes of carbon dioxide by means of its own road traffic initiatives. However, the actual outcome was approximately 101,000 tonnes.

The 2010 target was allocated to various units within the organization – Trafikverket Region Stockholm’s task was to lower carbon dioxide emissions by 4,000 tonnes. The 2011 target for the region is to lower emissions by 4,100 tonnes. An estimated reduction of 10 km/hour on the stretch in question would meet approximately 25 per cent of the region’s 2010 target and 24 per cent of its 2011 target.

9 Noise along E18 through Danderyd

9.1 Background

There is a risk along the most heavily trafficked roads in Stockholm County that exposure of residents to noise will exceed the Riksdag’s target values.

In addition to measures for reducing or re-routing car traffic, Trafikverket has built anti-noise barriers at the most exposed points or installed sound insulated windows in the households that are most exposed to noise. Nevertheless, noise exposure is perceived to be unsatisfactory in some areas.

In 2005, Ramböll (on behalf of the Hellström & Partners law office) calculated noise levels along E18 in Danderyd. The daily equivalent noise level target of 55 dBA was exceeded at many points. Noise levels may be higher for apartment buildings with more than two storeys, given that Ramböll’s study was conducted only at ground level and the second storey (5 metres above ground level). This study used the noise map for the second storey. Traffic flow was estimated at 72,600 vehicles per day, 6.4 per cent heavy. Table 5 presents the speeds that were used.

9.2 Calculation method for describing the impact of speed on noise levels

The calculation model of the Swedish Environmental Protection Agency can be used to analyse the impact of variable speeds along E18. The studies for this report were limited to analysing estimated changes in noise emissions due to speed differences (speed limits, actual speed or assumed speed). The change in noise emission is assumed to generate the same

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change in nuisance levels along the road. It was not deemed necessary to update Ramböll’s
study given that the changes were less than 2.5 dBA and barely visible on the noise map.

9.3 Traffic 2010
Since 2009, traffic on E18 through Mörby has been measured in two sections – north of
Danderyd Hospital and south of Danderyd Church. Total traffic flow in 2010 averaged
approximately 68,000 vehicles per day, a decrease of approximately 4,000 since 2005.
Approximately 10 per cent were heavy vehicles.
Since 2005, speed limits, assumed speed and actual speed have changed as follows on the
three stretches that were studied.

Table 5: Speed on E18 through Danderyd.

<table>
<thead>
<tr>
<th>Stretch</th>
<th>Speed limit, 2005</th>
<th>Assumed speed (Ramböll 2005)</th>
<th>Speed limit, 2010</th>
<th>Actual speed, 2009-2010</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Southbound</td>
<td>Northbound</td>
<td>Southbound</td>
<td>Northbound</td>
</tr>
<tr>
<td>Interchange 180 Danderyd Church – Interchange 179 Mörby</td>
<td>90</td>
<td>90</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>Interchange 179 Mörby – Interchange 178 Danderyd Hospital</td>
<td>90</td>
<td>90</td>
<td>90</td>
<td>90</td>
</tr>
<tr>
<td>Interchange 178 Danderyd Hospital – Interchange 177 Inverness</td>
<td>70</td>
<td>70</td>
<td>70</td>
<td>70</td>
</tr>
</tbody>
</table>

9.4 A corrective measure
Noise levels are affected by vehicle speed. Reduced speed could lower noise emissions in
accordance with Table 6. The assumption is that average speed is reduced by 5 and 10
km/hour respectively. The alternative that northbound speed limits would be observed so
well that actual average speed was equal to the speed limit is also analysed
requires better surveillance).
Table 6: Possible noise reduction on E18 through Danderyd by reducing average speed (compared with actual speed in accordance with Table 5).

<table>
<thead>
<tr>
<th>Stretch</th>
<th>Reduced equivalent noise level (dBA)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Actual speed -5 km/h</td>
</tr>
<tr>
<td>Interchange 180 Danderyd Church – Interchange 179 Mörby</td>
<td>-0.6</td>
</tr>
<tr>
<td>Interchange 179 Mörby – Interchange 178 Danderyd Hospital</td>
<td>-0.7</td>
</tr>
<tr>
<td>Interchange 178 Danderyd Hospital – Interchange 177 Iverness</td>
<td>-0.7</td>
</tr>
</tbody>
</table>

Additional reduction of average speed to -15 and -20 km/h compared with measured speed would further lower sound levels by 0.7 and 1.4 dBA respectively.

The daily equivalent noise level target of 55 dBA is exceeded for an estimated 700 households, which corresponds to approximately 1,750 residents (see Table 7). If speed were reduced by 10-15 km/hour, noise levels would be lowered by 1.5-2 dBA for all of these households, as well as households whose noise levels are just below the target values. Trafikverket currently has no data about the number of schoolchildren or hospital patients who are affected. If sound levels are lowered by 1.5-2 dBA, the target value of 55 dBA will be met for approximately 160 households, corresponding to 400 residents.

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13 Actual average speed, which is lower than the speed limit, is used for southbound traffic.
### Table 7: Estimated number of buildings exposed to noise, as well as decrease in the number of buildings that would exceed target values as the result of a calculated speed reduction of 10-15 km/hour.

<table>
<thead>
<tr>
<th>Stretch</th>
<th>Apartment buildings</th>
<th>Single-family dwellings</th>
<th>Schools</th>
<th>Other</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Before</td>
<td>After</td>
<td>Before</td>
<td>After</td>
</tr>
<tr>
<td>Interchange 180 Danderyd Church – Interchange 179 Möby</td>
<td>45</td>
<td>45</td>
<td>55</td>
<td>Approximately 50</td>
</tr>
<tr>
<td>Interchange 179 Möby – Interchange 178 Danderyd Hospital</td>
<td>375</td>
<td>265</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Interchange 178 Danderyd Hospital – Interchange 177 Inverness</td>
<td>185</td>
<td>155</td>
<td>35</td>
<td>20</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>605</td>
<td>465</td>
<td>90</td>
<td>70</td>
</tr>
</tbody>
</table>

The long-term target is that nobody be exposed to equivalent noise levels above 55 dBA. Approximately 71,000 residents along national roads in Stockholm County have an equivalent noise level above 55 dBA. Trafikverket’s primary strategy for reaching the target is to reduce noise at the source, i.e., to lower noise emissions from vehicles (including the use of speed limits), as well as by using less noisy surfacing. All possible measures must be employed if the target is to be reached. In this case, a reduction of 1.5-2 dBA would promote attainment of the target. Four hundred residents represent 0.5 per cent of those exposed to noise in accordance with the above. Given that the target for 2020 is a modest 5 per cent, this measure would make a 10 per cent contribution towards attainment of the region’s 10-year target.
10 Discussion and conclusions

The results presented in this report are in line with a number of previous studies. Use of studded tyres aggravates road surface wear and tear when vehicle speed increases (VTI notation 21, 1997; VTI 543, 2006). In addition to speed, wear and tear is due to the type of surfacing, the type of studs and whether the roadway is dry or moist. Studies with pavement testing machines have shown that PM$_{10}$ formation increases along with speed (Gustafsson et al., 2009; VTI Report 520, 2005).

Measurements when various types of tyres are used along roads in actual traffic environments demonstrate a clear correlation between vehicle speed and PM$_{10}$ formation (Hussein et al., 2008; Pirjola et al., 2009). Similarly, measurements in the Södra länken Tunnel in Stockholm have shown that PM$_{10}$ emissions depend on speed (Kristensson et al., 2004).

However, not many studies have quantified the possible impact of speed reduction on particulate levels along the roads. Reducing average speed on National Road 4 in Oslo by approximately 10 km/hour substantially lowered PM$_{10}$ levels (Hagen et al., 2005). The biggest particles (coarse particle fraction; particles with a diameter of 2.5-10 µm), which come primarily from road surface wear and tear, were approximately 39 per cent lower, while the average reduction for all particles smaller than 10 µm (PM$_{10}$) was estimated at approximately 36 per cent. Total PM$_{10}$ levels, which are also affected by other sources such as wood heating, also decreased but not as much (approximately 20 per cent). Given that studded tyre use was considerably lower in Oslo (approximately 25 per cent), speed reduction should be a very efficient way to reduce emissions in Stockholm were studded tyre use is much more common than in Oslo.

Reduced speed and more uniform traffic flow were also tested in the Netherlands, but the impact on particulate levels was very little (IPL-8, 2009). Because studded tyres are not used in the Netherlands, the results cannot be compared with the analysis and measurements presented in this report. Studies in the United States and other countries where studded tyres are not used have also shown that vehicle speed affects whirling up of particles from the road surface (Abu-Allaban et al., 2003; Kuhns et al., 2001; Countess et al. 2001).

The impact of vehicle speed on air quality along Road E18 Norrtäljevägen, Road 75 Södra länken and Road E4/E20 Essingeleden has been calculated in this study on the basis of regression coefficients for the ratios of PM$_{10}$ levels to NO$_x$ levels for each data set. It should be noted that the speed correlations in this study refer to motorways/approach roads with speeds of 50-100 km/hour, approximately 5-7 per cent heavy vehicles and 60-70 per cent use of studded tyres.

Most likely particulate emissions along these roads are primarily a direct consequence of wear and tear rather than accumulated material on the road surface. Only salt (not sand) is used for anti-skid treatment on approach roads. The emission factors cannot be applied to central city streets where road and traffic conditions are often different; jerkier driving can aggravate wear and tear, more accumulated material on the road means that a larger percentage of particulate emissions are due to suspension, the use of sand in combination with salt can aggravate wear and tear of the road surface and contribute to whirling up of particles, etc. Mobile measurements indicate that the impact of speed on PM$_{10}$ emissions decreases at lower speeds (below approximately 50 km/hour) (Hussein et al., 2008). Additional studies are required to explore the impact of vehicle speed at other points. PM$_{10}$ emissions at the points studied were due primarily to road surface wear and tear. Vehicle speed affects not only particles that generate wear and tear, but particles and gases in exhaust fumes. Thus, reduced vehicle speed lowers emissions from exhaust fumes and thereby their health and environmental effects.
Conclusions

- The emission factors have been shown to be equally large and significant at all points, which confirms that the correlations are reliable and have not arisen coincidentally.
- The average emission factor for all points in 2009-2010 is $68 \pm 8$ mg PM$_{10}$/fkm per 10 km/hour change in speed. A regression analysis of measurement data from Road E18 (at the height of Kyrkskolan) yields an emission factor of $79 \pm 40$ mg PM$_{10}$/fkm per 10 km/hour.
- Using the correlation arrived at for Road E18, the possible impact of various speed reductions on PM$_{10}$ levels has been calculated. The analysis shows that a daytime (6 am to 6 pm) reduction of average speed by 2, 5, 10 and 20 km/hour could lead to 0, 4, 8, and 12 fewer days respectively with levels above the limit of 50 µg/m$^3$.
- To bring the number of days with levels above 50 µg/m$^3$ below 35 (in accordance with the environmental quality standard), average speed would have to be reduced by more than 20 km/hour (under the conditions that prevailed in December 2009 – May 2010, and if only speed was used as a tool to change pollution levels).
- The impact of speed reduction on the number of days with levels above 50 µg/m$^3$ is largely dependent on weather conditions in the spring when PM$_{10}$ levels are highest. It goes without saying that the chances of lowering the number of days with levels above 50 µg/m$^3$ improve if the level is often just above 50 µg/m$^3$ compared with if it is considerably higher.
- Speed reduction also lowers the average level, which reduces total population exposure and thereby the health effects of particulate emissions. Studies suggest that there is a linear relationship between particulate levels and health effects and that there is no threshold below which the levels have no impact on health (Forsberg & Segerstedt, 2004).
- CO$_2$ emissions could decrease by approximately 7 per cent if average speed (for purposes of calculation) were reduced by 10 km/hour on the E18 stretch through Danderyd (approximately 2.8 km).
- The daily equivalent noise level target of 55 dBA is exceeded for an estimated 700 households, which corresponds to approximately 1,750 residents. If speed were reduced by 10-15 km/hour, noise levels would be lowered by 1.5-2 dBA for all of these households. The target value of 55 dBA will even be met for approximately 160 households, corresponding to 400 residents.
11 References

For references, see the complete Trafikverket Publication 2011:042 "Miljöanpassad hastighet på E18" (Environmentally Adapted Speed on E18), on Trafikverket’s website http://www.trafikverket.se/Privat/I-ditt-lan/Stockholm/Miljoanpassad-hastighet/