AIR QUALITY MODELLING OF STRATEGIC TRAFFIC DEMAND MANAGEMENT STRATEGIES

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ABSTRACT

This paper presents the results of the air quality modelling study carried out within the HEAVEN (Healthier Environment through Abatement of Vehicle Emission and Noise) EU: Fifth Framework Information Society Programme. The HEAVEN system in Leicester has identified potential scenarios for better air quality through improved control and management of traffic. These measures have been of two types; short-term tactical and long-term strategic measures. In the HEAVEN project emphasis was placed on developing and quantifying the impact of the more strategic citywide traffic demand management strategies (TDMS). Four TDMS scenarios were designed to assess the sensitivity to changes in speed and fleet composition of the network against the base case. However, two of the TDMS, namely those to assess the effect of reducing speed of traffic by 20% on all links across the network and to remove all HGV, were not realistic because they did not also consider the changes in the capacity of the network for traffic that would result. When the capacity reducing effects of the road network were investigated it was found that if a speed reduction of 20% were imposed the capacity would be substantially reduced and if all HGV were banned the capacity would increase. This capacity effect was measured using the TRIPS model and the results inputted into the air quality model Airviro. This paper presents the air quality impacts of the realistic scenarios and compares them to those for the sensitivity tests.

1. INTRODUCTION

Road transport is a major source of atmospheric emissions affecting air quality in the UK, particularly in urban area – though there are other sources, primarily industry and domestic. These emissions affect those who do not as well as who do own vehicles. The two pollutants of most concern are oxides of nitrogen and particulates. For these and other pollutants, the UK Government has set air quality targets to be met throughout the country. Local authorities have a key role to play in improving local air quality and many have already demonstrated a strong commitment to adopting appropriate and effective transport measures that help to achieve air quality targets [1].

In order to understand the impact of air pollution on health it is important to have estimates of air pollutant concentrations at strategic locations in an urban area. This can be achieved by direct measurement or by numerical modelling. As monitoring systems tend to be expensive both to purchase and maintain, it is impossible to have a large number of installations in a city or urban area. Therefore, it is common practice to employ a combination of monitoring and modelling to assess air quality. While the monitoring sites can have a wide spatial coverage, they clearly provide only a limited representation of pollutant concentrations over an area. In addition they cannot be used, in a simple way, to project future concentrations and to assess exceedances due to various transport scenarios. As a result, modelling becomes essential to understand the effect of emissions and atmospheric conditions on pollutant concentrations and thus to estimate future concentrations and exceedances taking into account changes in vehicle fleet and proposed transport policy measures [2].

This paper presents the results of the air quality modelling study carried out in Leicester, UK to assess the air quality impacts of selected strategic traffic demand management strategies. This study was carried out within the HEAVEN (Healthier Environment through Abatement of Vehicle Emission and Noise) EU: Fifth Framework Information Society Programme.

2. STRATEGIC TRAFFIC DEMAND MODELLING STRATEGIES

The HEAVEN system in Leicester has identified potential scenarios for better air quality through improved control and management of traffic [3]. These measures have been of two types; short-term tactical and long-term strategic measures. Short term tactical traffic demand management strategies have been described elsewhere [4]. In the HEAVEN project emphasis was placed on developing and quantifying the impact of the more strategic citywide traffic demand management strategies (TDMS). A base and four TDMS scenarios were designed to assess the sensitivity of the network to changes, namely:

Base Scenario (*base case*) – Year 2001 scenario with model runs for average winter and average summer meteorological conditions.

Scenario 1 (*01speed20*) - A homogenous speed reduction of 20% for the whole running fleet ignoring capacity effects.

Scenario 2 (*01nohgv*) - A vehicle fleet without heavy goods vehicle (>3.5t), the HGV proportion not allocated among the other vehicle categories and capacity effects ignored.

Scenario 3 (*noroads*) - A scenario without traffic related emissions.

Scenario 4 (*newtech*) - A scenario anticipating for each type of vehicle fleet the implementation of the most advanced legislation, Euro IV in this case.

However, two of the TDMS, namely those to assess the effect of reducing speed of traffic by 20% on all links across the network and to remove all HGV, from traffic modelling perspective were not realistic because they did not consider the effect on the capacity of the network. When the capacity reducing effects of the road network were modelling using TRIPS (TRansport Improvement Planning System) it was found that if a speed reduction of 20% were imposed, 18% of the traffic would not be able to travel and the capacity would be substantially reduced. This means that the peak period is spread over a longer duration, creating increases in pollution during the time leading up to the peak period and after the peak. Also, the 18% less traffic spends more time in the network by driving at a slower speed. This creates more delay resulting in a 9.2% increase in journey time. If all HGV were banned it has the effect of increasing speed of traffic on some links resulting in increased capacity. The magnitude of these capacity effects, estimated by the TRIPS transportation model, was input to the air quality model Airviro as scenarios *nohgv* and *speed20*.

3. AIR QUALITY MODELLING

Airviro air quality dispersion model was used for determining the concentrations resulting from changes in traffic as a result of TDMS. Airviro was set-up for Leicester for the year

2001 using emission database for point, area and road sources. It was decided to test all the scenarios for two distinct seasons, summer and winter representing average and acute meteorological condition. Summer scenario contained meteorological data from 1 April to 30 September, while winter scenario contained the data from 1 Jan to 31 March 2001 and 1 October to 31 December 2001. The *base case* setup was then modified for each TDMS and using the summer and winter statistics, derived from the last five years observed weather data. The Gaussian module of Airviro was executed.

To simulate the 'higher' levels of conditions, the air quality model (Airviro) was run for AM peak hour (8-9 AM) skipping remaining hours for simulation. Three pollutants have been modelled for each scenario viz. NO_x, CO and PM_{10}. Air quality was simulated at 250m x 250m grid resolution for an area of 15 x 17 sq km. The concentrations of NO_x, CO and PM_{10} were simulated at 4080 locations for all scenarios including the *base case*.

4. RESULTS AND DISCUSSION

A summary of the predicted winter and summer concentrations is presented in Table 1. It is clear that, irrespective of pollutant type and scenario, concentrations are higher for winter compared to summer. Comparing the *noroads* scenario with the *base case*, 93%, 99.7% and 96% of of total concentrations of NO_x, CO and PM_{10} respectively are due to traffic in the winter. In the summer, 96%, 98.8% and 98% of total concentrations of NO_x, CO and PM_{10} respectively are due to traffic. An interesting observation is that whilst the absolute levels reduce in summer compared to winter the relative proportion changes increase in the case of NO_x and PM_{10}. This may be due to the formation of secondary pollutant depending on levels of ozone in the case of NO_x. The pollutant concentration maps for CO for winter for the *base case*, *speed20*, and *nohgv* respectively are presented in Figures 1-3. This analysis has demonstrated the significance of traffic as a source of pollution and the overall reduction in all pollutant concentrations during the summer compared to the winter.

Reducing the speed of all vehicles across the network was shown in the sensitivity analysis, in winter, to increase pollutant concentrations slightly over the base scenario, 1.4%, 16.3% and 9.7% of total concentrations for NO_x, CO and PM_{10} respectively. In the summer, similar increases in pollutant concentrations over the base scenario, of 1.4%, 16.2% and 10.8% of total concentrations for NO_x, CO and PM_{10} respectively were observed. The effect of reducing speed on increasing the CO and PM_{10} emissions is marked. However, Table 1 shows more importantly that the impact that reducing speed has on reducing the capacity of the network, should not be ignored. The results of modelling the capacity effects with TRIPS showed that the network capacity reduces substantially. Firstly, 18 % less traffic is able to complete their journeys in the peak hour and consequently the peak period is spread over a longer duration. Also, the 82% traffic travelling in the peak spends more time in the network by driving at a slower speed. This creates more delay resulting in a 9.2% increase in journey time. This means that traffic rat runs and travels longer distances. The resulting effect, in winter, is to increase emissions by 116%, 175% and 202% for NO_x, CO and PM_{10} respectively, and in summer to increase emissions by 119%, 175% and 1.5% for NO_x, CO and PM_{10} respectively. This substantial increase in all pollutants would be totally unacceptable and therefore not an option for Leicester. The pollutant concentration map for CO for winter scenario is presented for the realistic speed reduction scenario in Figure 2. The dramatic impact on the distribution of pollutants across the whole network is clearly evident.

Turning now to the scenario that considers prohibiting all heavy goods vehicles, a different picture is presented. With reference to Table 1 for *01nohgv* modelled without consideration of capacity changes, in winter, results in a decrease in pollutant concentrations significantly compared to the base scenario. The decreases amount to 31.9%, 12.7% and 28.6% for NO_x, CO and PM_{10} respectively. In the summer, similar reductions in pollutant concentrations over the base scenario, of 32.9%, 2.1% and 30.0% for NO_x, CO and PM_{10} respectively were observed. Modelling the capacity effect of no HGV with TRIPS however, showed that the network capacity, whilst having some impact, was not as dramatic an effect as the speed reduction. One of the effects of the removal of HGV is to reduce the volume of traffic on the roads. This reduces all emissions. However, on some roads, especially where the volume of HGV is high, the reduced level of traffic flow generally has the effect of increasing speed of traffic. Depending on the change in speed and from what base level the change in resulting pollutant level will differ depending on the pollutant. In addition, traffic may re-route to shorter paths as a result of reduced flow on some links. The effect on traffic flows and speeds is not straightforward; the effect can be large on some links and small on others and will be different for the different pollutants depending on the initial and level of change in speed. Overall for *nohgv* scenario, the TRIPS modelling predicted a 28% improvement in network travel time for AM and PM peaks compared with the base case. The resulting effect in winter is to decrease concentrations by 35.8%, 12.7% and 28.6% for NO_x, CO and PM_{10} respectively, and a similar decrease for all pollutants in summer amounting to 36.5%, 12.1% and 28.5% for NO_x, CO and PM_{10} respectively. A comparison of the *nohgv* with and without TRIPS shows that whilst there is only a small difference in the PM_{10}, ignoring capacity effects overestimates the reduction of NO_x, by 3.9%, 3.6% and of CO by 10.6% and 10.0% for winter and summer respectively. The pollutant concentration map for CO for the realistic nohgv scenario for winter is shown in Figure 3. The dramatic impact on the reduction and distribution of pollutants across the whole network is clearly evident.

As expected, the *newtech* scenarios result in significantly lower concentrations compared to the Base Case. In winter, this would amount to 78.2% and 87.4 % for NO_x and PM_{10} respectively. In the summer, slightly higher reductions are anticipated of 80.8% and 88.5% for NO_x and PM_{10} respectively.

5. CONCLUSION

Air quality modelling is essential to assess the links between estimation of emissions and of atmospheric concentrations and to estimate future concentrations and exceedances. This paper presented the results of the air quality modelling study carried out in Leicester, UK to assess the air quality impacts of selected strategic traffic demand management strategies. Four TDMS scenarios were identified to assess against the *base case* the sensitivity of the network to changes in speed and fleet composition. Scenarios were investigated with and without considering the consequential changes in the capacity of the network. When the capacity reducing effects of the road network were investigated it was found that if a speed reduction of 20% were imposed the capacity would be substantially reduced and if all HGV were banned the capacity would increase, with significant impact on emissions thus emphasising the importance of considering capacity effects. This air quality modelling work has shown the significance of traffic as a source of pollution and that, irrespective of pollutant type and scenario, concentrations are higher for winter compared to summer. This work has demonstrated that the capacity effects have to be modelled to provide realistic assessments of the impact of TDMS designed to reduce the levels of pollution in networks.

6. REFERENCES

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A. Winter

Scenario	**NO_x**	**CO**	**PM_{10}**	**Note**
	μg/m^3			
Base Case	33.97	93.14	1.75	
Speed20	73.33	255.92	5.28	With TRIPS modelling
01speed20	34.45	108.35	1.92	Without TRIPS modelling
nohgv	21.80	81.31	1.25	With TRIPS modelling
01nohgv	23.13	91.17	1.23	Without TRIPS modelling
*Newtech**	7.41	93.14	0.22	
Noroads	2.38	0.29	0.07	

B. Summer

Scenario	**NOx**	**CO**	**PM_{10}**	**Note**
	μg/m^3			
01 Base	25.03	70.24	1.30	
Speed20	54.93	192.98	1.32	With TRIPS modelling
01 Speed20	25.39	81.64	1.44	Without TRIPS modelling
NoHGV	15.88	61.72	0.93	With TRIPS modelling
01 NoHGV	16.79	68.74	0.91	Without TRIPS modelling
NewTech*	4.79	70.24	0.15	
NoRoads	0.96	0.11	0.03	

* *newtech* scenario was modelled with new emission factors (Euro IV) for NO_x and PM_{10} only but not for CO, as they are still not recommended by UKEFD (UK Emission Factor Database). CO values for *newtech* scenario are same as those for *01base* for this reason.

Table 1: Variation in pollutant concentrations across network

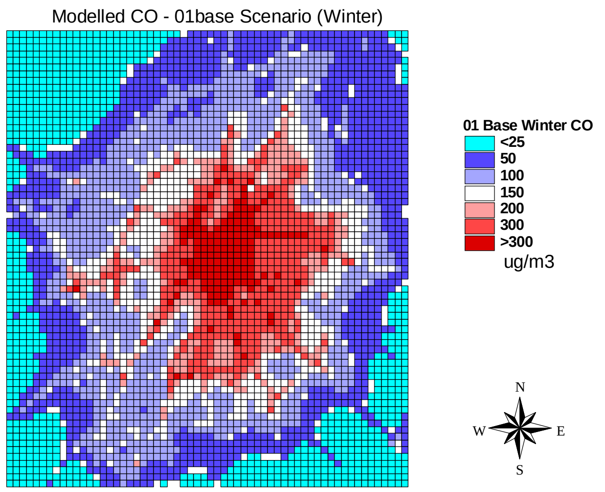

Figure 1: Modelled concentrations of CO the Base-Case (winter)

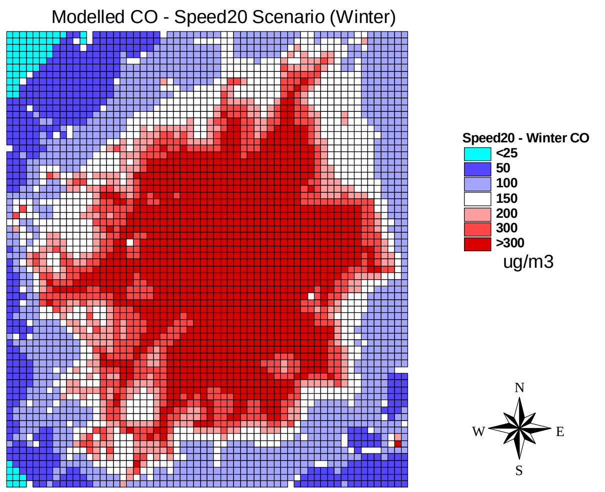

Figure 2: Modelled concentrations of CO for *Speed20* Scenario (winter)

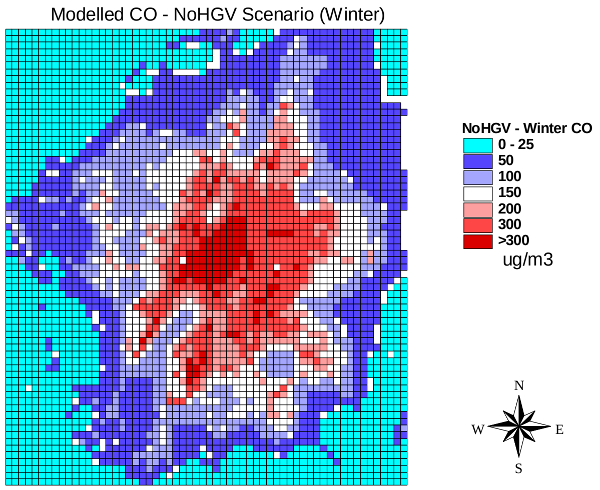

Figure 3: Modelled concentrations of CO for *nohgv* scenario (winter)