THE FUTURE OF TRANSPORT

# CLIENT PROJECT REPORT CPR2252

## Emissions and air quality assessment of a 20 mph speed limit in the Lutterworth AQMA

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## Report details

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## Disclaimer



## Contents amendment record

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# Executive summary

As part of Harborough District Council's requirements under the Local Air Quality Management (LAQM) regime, the local authority declared an Air Quality Management Area (AQMA) for Lutterworth town centre due to exceedances of the annual mean nitrogen dioxide ($NO_2$) objective. The local authority has recently adopted a new air quality action plan framework and is working with the County to design Highways schemes to improve emissions and air quality. One of these potential schemes includes introducing a 20 mph zone in the Lutterworth AQMA.

The purpose of this study was to determine through a modelling assessment whether the introduction of this 20 mph zone could improve traffic related emissions and concentrations. This modelling based study involved collecting real-time second by second data using an instrumented vehicle as part of a drive cycle survey conducted over one day in the existing 30 mph speed limit and to simulate a 20 mph speed limit. These data were analysed through an instantaneous emissions model to determine emissions of nitrogen oxides ($NO_x$), particulates (PM) and carbon dioxide ($CO_2$) and subsequently modelled to obtain $NO_2$ and $PM_{10}$ concentrations. Data on the local vehicle fleet were obtained specifically for this study from an ANPR camera survey.

The results found that there were more 15,609 vehicles travelling along the road in a 24 hour period of which 30 percent were from through traffic. 94 percent of these vehicles were light duty (i.e. cars and vans) and the majority of these were diesel fuelled (63 percent). In terms of the contribution to emissions, light duty vehicles were responsible for around 45 percent of $NO_x$ emissions, 70 percent of $PM_{10}$ emissions and 75-80 percent of $CO_2$ emissions. The average speed across all drive cycle runs was below the existing 30 mph (48 km/h) speed limit with the maximum recorded speed being 45 km/h.

The simulation of a 20 mph (32 km/h) speed limit resulted in a reduction of average speed across all runs of around 4 km/h to 24.5 km/h (15 mph). There was also a reduction in the standard deviation from 12-13 km/h in the 30 mph speed limit to 8 km/h in the simulated 20 mph limit. This reduction in speed led to a positive effect by dampening acceleration events by up to 30 percent resulting in a modelled reduction in average NOx, PM and $CO_2$ emissions across entire route by around 5 percent.

A number of adjustments were made as part of the verification process conducted for the concentration modelling. These included splitting the emission estimates into specific areas along the route, incorporating the impact of gradient and adjusting the emissions to better represent real driving NOx emissions. The model was run at the façade of 371 properties and found that there was an average reduction in modelled annual mean $NO_2$ concentrations by 3 percent (equal to 1.2 $\mu g/m^3$) with a maximum reduction of 15 percent (approximately 6.8 $\mu g/m^3$). There were some close to the roadside on Market Street, where the road has a relatively steep gradient of 3.1% where an increase in concentration was modelled. However, the overall net reduction in the population weighted $NO_2$ concentration was 5 percent across the modelled area.

Coloured contour maps were produced providing a visual representation of $NO_2$ and $PM_{10}$ dispersion. For annual mean $NO_2$, the primary pollutant of concern, the maps clearly suggested that a speed limit reduction may spatially improve pollution along the High

Street/Market Street areas. The maps also indicated that subject to location, benefit may be transferred up to 75m from the roadside

On this basis, it is recommended that Harborough District Council considers the business case to impose a 20 mph speed limit. As well as including the cost benefits of improved air quality it may also like to consider other complementary environmental gains to offset the capital costs.

## Contents

## List of Figures

# List of Tables

# 1 Introduction

## 1.1 Air quality in Lutterworth

Harborough District Council is a large rural authority located in Southern Leicestershire. There are two major towns in the district; Market Harborough and Lutterworth. The district has excellent traffic links including the M1, M6 and A14 running through the district and Midland mainline railway.

Under the requirements of the Local Air Quality Management (LAQM) process as set out in Part IV of the Environment Act (1995) and UK Air Quality Strategy (AQS), all UK local authorities are obliged to regularly review and assess air quality in their areas. As part of this process, local authorities need to determine whether or not health-based AQS objectives are likely to be achieved. Where exceedances are considered likely, the local authority must then declare an Air Quality Management Area (AQMA) and prepare an Air Quality Action Plan (AQAP) setting out the measures it intends to put in place in pursuit of the objectives.

In 2001 as part of the LAQM process, Harborough declared an AQMA for Lutterworth town centre due to exceedances of the annual mean nitrogen dioxide ($NO_2$) objective to meet a concentration of 40 $\mu g/m^3$. In 2012, following further assessment the AQMA was extended to the south (see Figure 1). The further assessment concluded that 85% of the vehicles travelling in Lutterworth were cars, with 6 percent heavy goods vehicles (HGVs) (Harborough District Council, 2012).

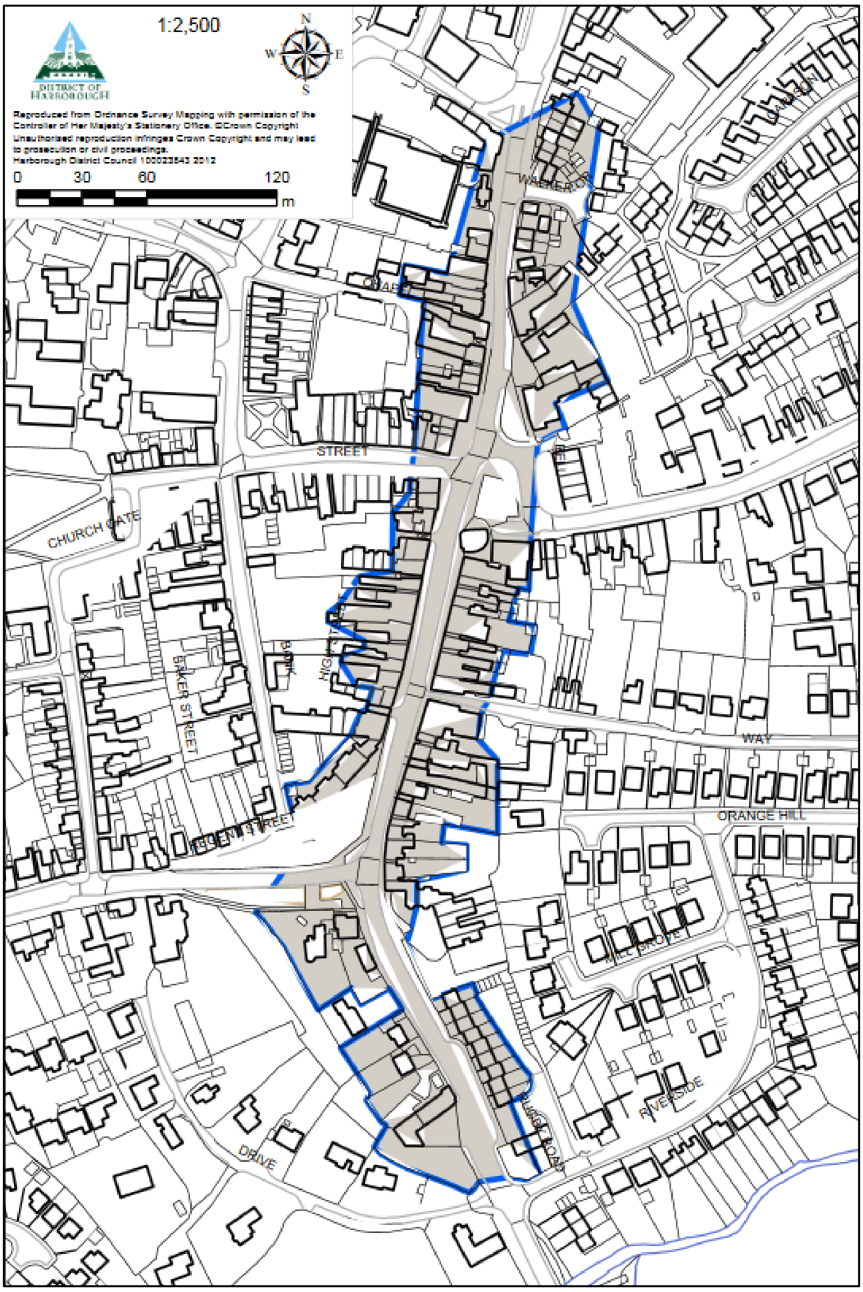


**Figure 1:** Lutterworth town centre AQMA boundary

The most recent information collected as part of the Council's LAQM process shows that there are measured exceedences of the annual mean $NO_2$ objective on the Rugby Road and High Street, Lutterworth and concentrations close to the objective at other locations within the AQMA (Harborough District Council, 2015). Recent concentrations from selected diffusion tube sites in the AQMA are given in Table 1 and a map of these locations is given in Figure 5.

**Table 1:** Annual mean $NO_2$ concentrations at selected roadside diffusion tube sites (2011-2015)

| Site ID | Location | Annual mean $NO_2$ concentrations ($\mu g/m^3$) | | | | |
|---|---|---|---|---|---|---|
| | | 2011 (BAF 1.06) | 2012 (BAF 0.87) | 2013 (BAF 0.83) | 2014 (BAF 0.8) | 2015* (BAF 0.83) |
| 01n | Lutterworth service shop | **49.5** | **48.7** | **45.5** | 39.8 | **44.6** |
| 18n | Jazz Hair, Lutterworth | **45.2** | **43.3** | **42.2** | 39.2 | 38.4 |
| 23n | 6 The Terrace, Lutterworth | 37.5 | 34.5 | 34.2 | 27.6 | 29.6 |
| 24n | 4-9 Regent Court, Lutterworth | 26.6 | **51.4** | **47.5** | 38.8 | **49.0** |
| 25n | 26 Market Street, Lutterworth | 35.8 | 31.1 | 37.8 | 34.9 | 35.2 |
| 26n | 24 Rugby Road, Lutterworth | **49.5** | **41.8** | **41.0** | **40.7** | **41.6** |
| 27n | 17 Rugby Road, Lutterworth | 36.8 | 33.9 | 32.9 | 29.8 | 33.1 |

*2015 data capture rates were higher than 75% except at site 01n and 23n

## 1.2 Aim and purpose of study

The local authority has had an Air Quality Action Plan for Lutterworth AQMA since 2004. The plan considered a range of measures to improve air quality including a Western Relief Road to divert traffic, introducing weight restrictions on the High Street, traffic calming measures and improvements to trunk roads including the M1. Although a number of these measures were considered, a relief road and weight restriction were deemed inappropriate due to local concerns. The local authority has recently adopted a new action plan framework and is working with the County on designing Highways schemes that can improve emissions and air quality. One of these potential schemes is to assess the impacts of introducing a 20 mph zone in the Lutterworth AQMA.

The purpose of this study is to determine through modelling whether the introduction of a 20 mph zone on the High Street in Lutterworth could improve traffic related emissions and therefore improve air quality within the AQMA.

## 1.3 Mapping

# 2 Methodology

This section outlines the methodology conducted to perform the modelling based emissions assessment.

## 2.1 Traffic data and vehicle fleet

To determine the coarse and detailed composition of the vehicle fleet in Lutterworth an Automatic Number Plate Recognition (ANPR) camera survey was conducted for 24 hours. These cameras are able to record vehicle registration (i.e. number) plates and this information is subsequently processed by the Department for Transport to match the details to the Driver Vehicle and Licensing Agency (DVLA) database.

The following steps were taken to determine the local fleet and traffic flow.

### *2.1.1 ANPR survey*

1. Lutterworth (High Street and Rugby Road) were surveyed to determine the optimal locations for the cameras.
2. Two cameras were set up from 00:00 on Tuesday 23rd February 2016 to 00:00 on 24th February 2016 at the locations indicated in Figure 2 to record north and southbound traffic.
3. Video traffic counts were taken in 15 minute periods at the camera locations to identify the percentage of registation plates recognised by the cameras.
4. Registration plates were verified for consistency using a bespoke checking programme to manually identify any misread plates.
5. Motorcycles were not included in the survye as the ANPR cameras are not able to accurately detect their numer plates
6. These data were used to determine the total 24 hourly traffic flow and coarse composition and further analysis to determine the detailed composition in terms of Euro emission standards (see Section 2.2.2).


Figure 2: Location of ANPR cameras in Lutterworth

Figure 3: Photograph of ANPR camera (northbound)

### *2.1.2 DVLA classification*

The DVLA classification process involved the following;

1. The number plate data from the cameras were formatted and matched to the DVLA database by the DfT.

2. Body type and tax class were used to classify vehicle types into the following categories; taxis, cars, light goods vehicles (LGVs), buses and coaches, rigid and articulate HGVs. The fuel type of each vehicle was also distinguished.

The Euro emission standard of each vehicle was estimated based on the date of first registration (see Table 2, its body type and category of vehicle (N1 etc).

**Table 2:** Date of introduction of Euro emission standards in the UK

| Vehicle | Euro 1/I* | Euro 2/II | Euro 3/III | Euro 4/IV | Euro 5/V | Euro 6/VI |
|---|---|---|---|---|---|---|
| Passenger car (M) | 1 July 1992 | 1 Jan 1996 | 1 Jan 2000 | 1 Jan 2005 | 1 Sept 2009 | 1 Sept 2014 |
| Taxi/Light commercial vehicle (N1-1) | 1 Oct 1994 | 1 Jan 1998 | 1 Jan 2001 | 1 Jan 2006 | 1 Sept 2009 | 1 Sept 2014 (diesel only) |
| Light commercial vehicle (NI-II, NIII | 1 Oct 1994 | 1 Jan 1998 | 1 Jan 2001 | 1 Jan 2006 | 1 Sept 2010 | 1 Sept 2015 (diesel only) |
| HGV (>3.5t) | 1 Jan 1992 | 1 Oct1998 | 1 Oct 2000 | 1 Oct 2006 | 1 Oct 2008 | 1 Jan 2013 |
| Buses (>5t) | 1 Jan 1992 | 1 Oct1998 | 1 Oct 2000 | 1 Oct 2006 | 1 Oct 2008 | 1 Jan 2013 |

*The dates in the table refer to all type approved vehicle models having to comply. There is usually a year grace to allow the changeover of existing and new vehicle models.

## 2.2 Emissions assessment

### *2.2.1 Drive cycle survey*

The first step in the emissions assessment was to conduct a drive cycle survey to collect second by second data which was subsequently used for further analysis and assessment using an instantaneous emissions model.

A drive cycle survey schedule was designed that allowed data to be collected at different times of the day in both directions along the A426 in Lutterworth, starting at Rugby Road through to High Street/Market Street. A survey car was instrumented with a VBox System[1] that reads the on-board diagnostic output to record a number of parameters that included speed and gear selection. The VBox recorder also includes a GPS receiver used to log the location and operation of the instrumented vehicle.

The survey was conducted on Thursday 3rd March 2016 whereby the driver undertook a car-following[2] method to test two styles of driving. The first represented the existing 30 mph speed limit along the road and the second represented a 20 mph speed limit. For the latter, the driver maintained a speed at or below the 20 mph limit during the survey. Over the course of the day, 69 independent surveys were driven across both directions. These data (second by second) were downloaded from the in-car recording system and visualised spatially using GIS software. A total of 19,658 data points were recorded for the entire survey

[1] https://www.vboxautomotive.co.uk/index.php/en/

[2] The driver literally tries to mimic the vehicle in front unless a certain alternative behaviour is required.

day of which 9,673 were recorded within the area of interest. An example that illustrates these points spatially is shown in Figure 4.

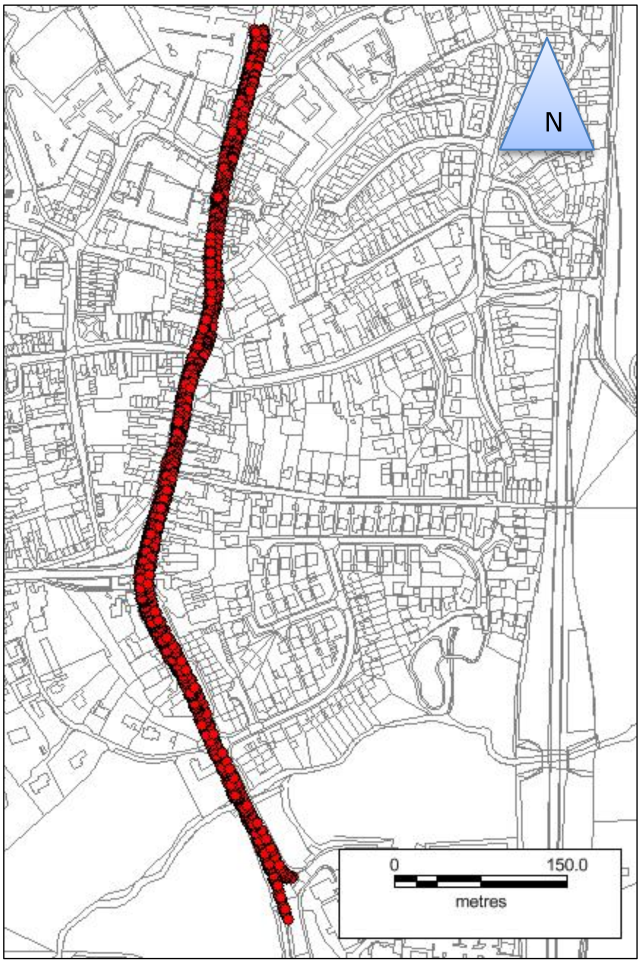


Figure 4: Example of drive cycle data points collected in Lutterworth

All logged data were checked in terms of spatial and operational integrity and were then processed into a format suitable for emissions modelling. Data were processed to identify individual driving cycles by time of day with specific driving styles and direction of travel and statistics including relative positive acceleration, deceleration, idling time, average speed at different times of day were calculated

### *2.2.2 Instantaneous emissions modelling*

The initial derivation of emission rates for nitrogen dioxide ($NO_x$), particulates (PM) and carbon dioxide ($CO_2$) from the drive cycle were analysed on a per vehicle basis (e.g. for a light and heavy duty vehicle) and then combined with traffic activity data obtained from the ANPR survey to estimate total emission rates for the road.

The PHEM (Passenger car and Heavy duty Emission Model) was considered the most appropriate tool for this study. PHEM calculates the engine power in one second intervals (1Hz) based on profiles of vehicle speed (the “drive cycle”), the road gradient, the driving resistances and the losses in the transmission system. The 1Hz cycle of engine speed is simulated based on the transmission ratios and a gear-shift model. Alternatively the cycle of engine load and/or engine speed can also directly be provided to the emission model.

All driving cycles were processed through PHEM. These values were then converted into grams for every second of the driving cycle based on consecutive paired values. PHEM only goes up to Euro 4 for light duty vehicles (LDVs) and Euro V for heavy duty vehicles (HDVs). Therefore emission factors for this standard were based on (optimistic) prognosis rather than based on engine testing. These assumptions for NOx and PM are given below. For $CO_2$ it was assumed that there was no change between Euro 4 and Euro 6:

- Euro 5 LDV - $NO_x$ emissions are 80 percent of Euro 4 and PM emission are 95 percent of Euro 4 limit for both diesel and petrol vehicles
- Euro 6 LDV – $NO_x$ emissions are the same for Euro 5. PM emission are 90 percent of the Euro 4 limit for both diesel and petrol vehicles
- Euro VI diesel HDV - $NO_x$ and PM emission are 80 percent of Euro 5 limit

Every paired speed combination produces a reference value which corresponds to a specific point on the engine emission map. From here, an emission factor is then selected. This produces several thousand output files. The following steps of further post processing were conducted to produce fleet weighted emission outputs for further emissions assessment.

1. Labelling of each run (per second) according to direction of travel and driving style using GIS spatial analysis tools
2. Summating emissions (g per vehicle) for each run split by LDV and HDV
3. Deriving distance weighted emissions rates (g/km) by dividing (2) by the distance travelled on each run.
4. Deriving light and heavy duty emission rates in g/km/day for each run. This was done by multiplying the LDV and HDV emissions for each time period by the LDV and HDV traffic flow for that same period and adding in an estimate of the night-time rate, i.e. 7pm to 7am (based on the lowest emission rate and multiplied by the flow in that period). The average for each time period were determined and summed to get emission in g/km/day.
5. Driving a total emission rate for north and southbound traffic in g/km/s by summing the LDV and HDV emission rates and converting emissions in g/km/day to g/km/s based on the number of seconds in a day. These rates are suitable for input into a dispersion model.
6. Emissions statistics in terms of average emissions per run, minimum and maximum were derived and the differences between the 30 mph and 20 mph runs were analysed.

## 2.3 Dispersion modelling

These emission data were used as the basis to conduct dispersion modelling to determine air quality concentrations at selected receptors along the High Street. The following tasks are outlined below.

### 2.3.1 Set up of dispersion model

The dispersion model (ADMS-Roads version 3.2) was set up to output concentrations of annual mean $NO_x$ and $PM_{10}$ from the road source only. A summary of the main features of the model inputs is given below.

- Road geometry including road width and canyon height of the links along the High Street, Rugby Road and Stoney Hollow.
- Emissions for each road link for each hour of the day based on the drive cycle emissions from the peak periods. The road links were divided up according to the polygons and are illustrated in Figure 5.
- Adjustment of emissions to taken into account the impact of gradient along the High Street. Emissions of vehicles driving up hill (northbound) were found to be higher than those in the southbound direction, with the highest emissions on the steepest gradients (polygons 2 and 4).
- Adjustment of $NO_x$ emissions take into recent evidence regarding higher real life emissions from diesel Euro 5 and 6 light duty vehicles.
- Hourly meteorological data from an appropriate local site in Church Lawford for 2015 (see Figure 6).
- OS co-ordinates and height of monitoring sites (see Figure 5) and relevant receptors. AddressPoint data was used to identify the relevant residential properties, and receptors were placed at the façade nearest to the road.

### 2.3.2 Model verification

To conduct the model verification process, the model was run to obtain annual mean concentrations using emissions for the existing 30 mph situation. 2015 was chosen as the verification year as this was the most recent year with a full monitoring dataset.

The model outputs for road $NO_x$ were verified against monitoring data from the diffusion tubes which were converted to road $NO_x$ concentrations using Defra's NOx-NO2 calculator tool. A background $NO_2$ concentration of 17.8 $\mu g/m^3$ was used in the modelling. This was obtained from the relevant 1km grid square from the 2013 Defra background maps (grid reference 454,500, 284,500)[3]. This value was slightly higher than the monitored concentrations from the local authority's urban background site. An adjustment factor was applied to the model outputs based on the agreement with the measured data (see Section 4). In the absence of any $PM_{10}$ monitoring data in the area, the adjustment factor was applied to $NO_x$ and $PM_{10}$ results.

### 2.3.1 20 mph scenario modelling

Following verification and model adjustment, the model was run for the year 2015 at individual relevant receptors at the locations indicated in Figure 7. The model was run for the existing 30 mph situation and for the predicted 20 mph situation. The concentrations were

[3] https://uk-air.defra.gov.uk/data/laqm-background-maps?year=2013

compared for the two scenarios to determine any differences at receptors in terms of population weighted change.

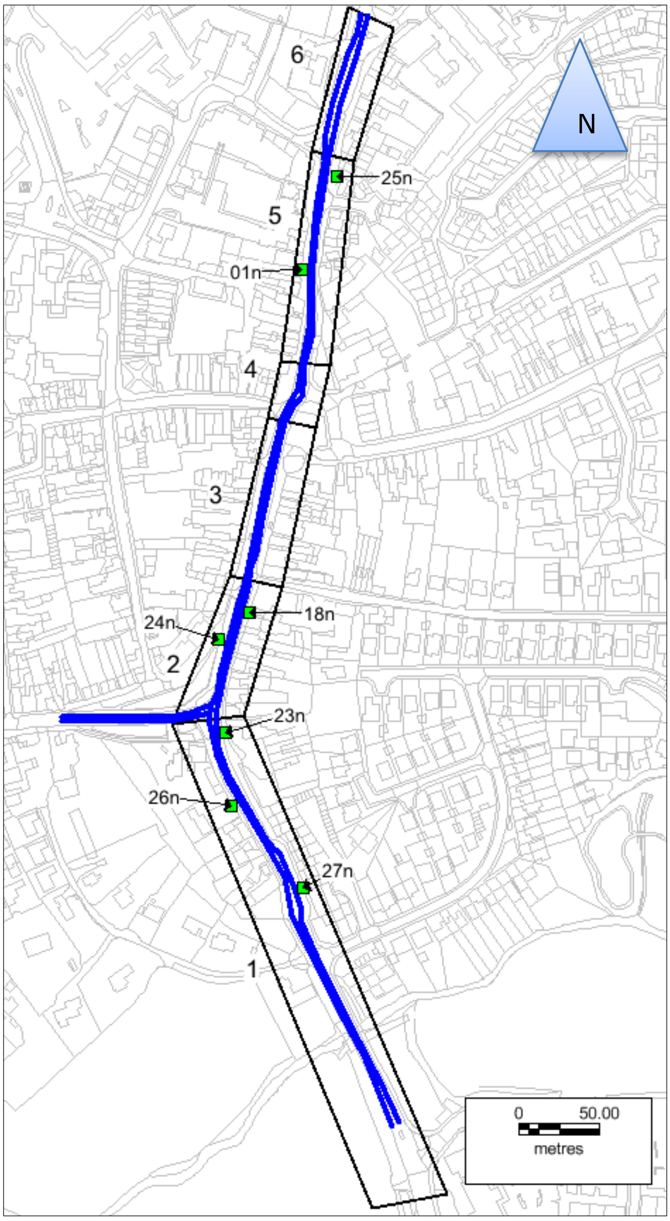


Figure 5: ADMS modelled road network and diffusion tube locations

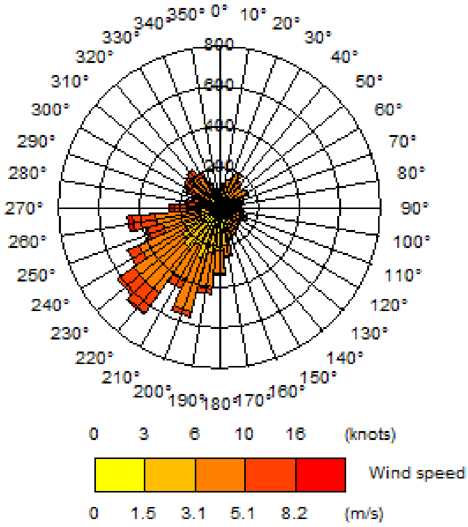


Figure 6: Wind speed and direction, Church Lawford, 2015

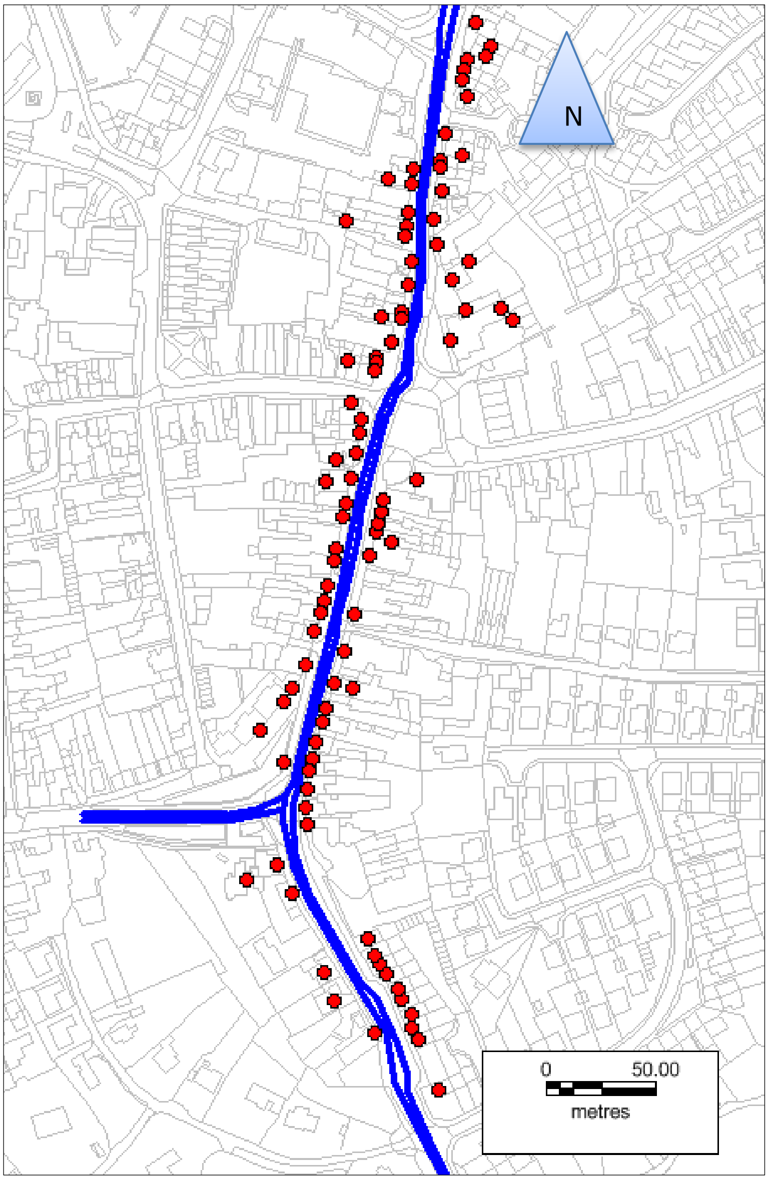


Figure 7: Location of relevant receptors at property facades

# 3 Results

## 3.1 Traffic data and fleet

### *3.1.1 Local fleet information*

This section provides a summary of key data extracted from the ANPR camera survey on the local vehicle fleet in Lutterworth in 2016.

The annual average daily traffic flow along the route surveyed (i.e. Rugby Road) was determined to be 15,609 vehicles with 7,984 (51 percent) in the northbound direction and 7,625 in the southbound direction (see Table 3). Based on the number of unique number plates and vehicles observed in both directions, the percentage of through traffic was estimated to be 30 percent.

The fleet composition was taken to be the same in both directions and the analysis found that 93.7 percent of the fleet were light duty vehicles (i.e. cars and vans) and only 6.3 percent were heavy duty vehicles (i.e. lorries and buses). Diesel vehicles dominate the fleet making up 64 percent of all vehicles observed. Of the light duty vehicles only, diesel cars and vans made up 62.5 percent (see Figure 8)

The majority of lorries in the fleet were the smaller rigid heavy goods vehicles (HGVs) under 20 tonnes in weight (see Figure 9). Although there are very few in the fleet (2.3 percent), the larger articulated HGVs were dominated by the largest vehicles which weigh over 40 tonnes (see Figure 10).

A number of fleet statistics are provided in the tables and figures below.

**Table 3:** Coarse vehicle composition

| | Composition by vehicle type | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Petrol car | Diesel car | Petrol LGV | Diesel LGV | Rigid HGV | Artic HGV | Bus/ coach | Total |
| Percentage | 35.0% | 48.3% | 0.03% | 10.4% | 3.9% | 2.3% | 0.1% | 100% |
| NB flow | 2,794 | 3,858 | 2 | 829 | 308 | 181 | 11 | 7,984 |
| SB flow | 2,668 | 3,685 | 2 | 792 | 295 | 172 | 11 | 7,625 |
| *Total flow* | *5,462* | *7,543* | *4* | *1,621* | *603* | *353* | *22* | *15,609* |

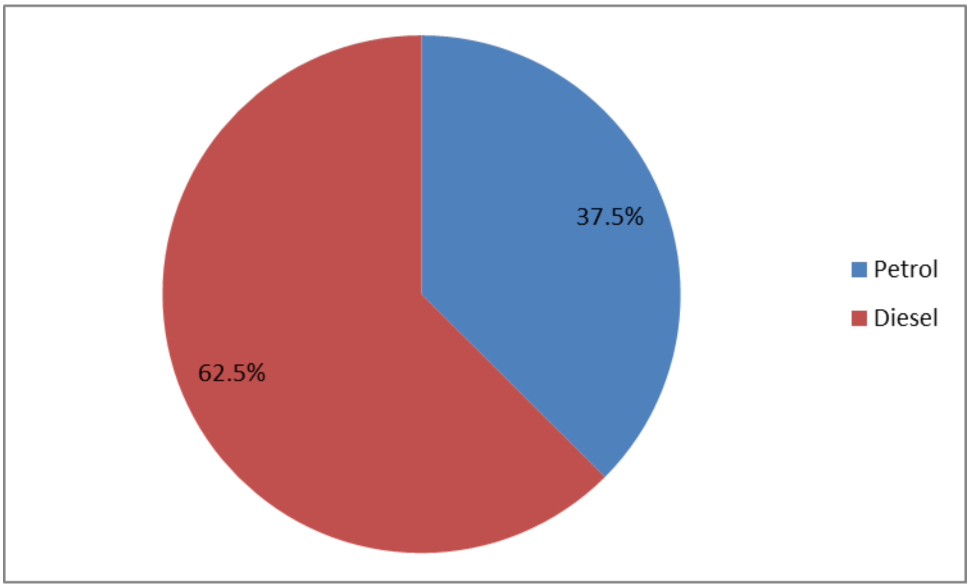


**Figure 8:** Petrol and diesel split of light duty vehicles (cars and LGVs)

**Table 4:** Breakdown of fleet by Euro emission standard

| Euro standard | Percentage composition | | | | | | |
|---|---|---|---|---|---|---|---|
| | Petrol car | Diesel car | Petrol LGV | Diesel LGV | Rigid HGV | Artic HGV | Bus /coach |
| Pre-Euro | 0 | 0 | 20% | 0 | 0 | 0 | 0 |
| Euro 1 | 0 | 0 | 0 | 0 | 1% | 0 | 0 |
| Euro 2 | 3% | 1% | 0 | 1% | 3% | 1% | 5% |
| Euro 3 | 26% | 10% | 20% | 12% | 15% | 7% | 64% |
| Euro 4 | 31% | 27% | 60% | 27% | 22% | 16% | 9% |
| Euro 5 | 30% | 51% | 0 | 59% | 31% | 42% | 5% |
| Euro 6 | 8% | 11% | 0 | 0 | 28% | 35% | 18% |
| *Total* | *100%* | *100%* | *100%* | *100%* | *100%* | *100%* | *100%* |

**Table 5:** Engine size of cars

| Engine size (cc) | Percentage | |
|---|---|---|
| | Petrol car | Diesel car |
| <1400 | 52% | 5% |
| 1400-2000 | 41% | 72% |
| >2000 | 8% | 23% |

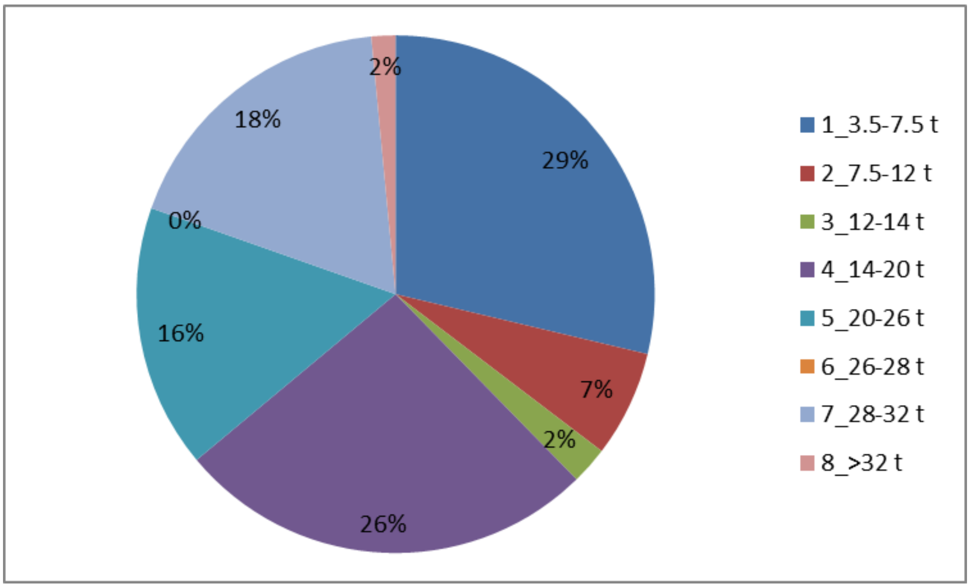


**Figure 9:** Breakdown of rigid HGVs by gross vehicle weight

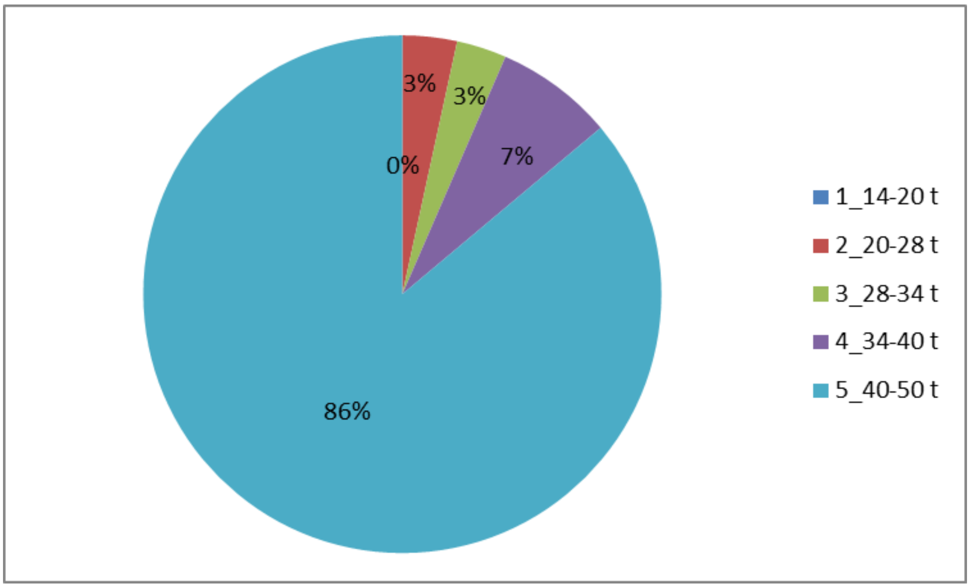


**Figure 10:** Breakdown of articulated HGVs by gross vehicle weight

### *3.1.2 Comparison with national statistics*

This section presents a comparison of the locally derived data against nationally available statistics to determine whether there were significant differences in the local fleet.

The Department for Transport (DfT) provide an annual count on the Rugby Road in Lutterworth. Data are available from 2000-2014[4]. The data trends show that there has been an overall increase in traffic flow over this time of 13 percent. The annual average daily traffic flow (AADT) not including motorcycles and cycles was around 15,000 vehicles a day in 2000 and this increased to a maximum of 18,200 vehicles in 2007. Traffic flow has since declined with a small increase in the last few years (see Figure 11). The DfT data provides an AADT of

[4] http://www.dft.gov.uk/traffic-counts/cp.php?la=Leicestershire#17073

around 17,300 in 2014 which is higher than the traffic flow obtained from this survey which was 15,609 in 2016. The DfT count is based on an automatic traffic counter which records data continuously each day and publishes an annual average based on each day of the year. In contrast, for this study, the ANPR camera survey was based on a single weekday's count in the winter. It is plausible that for various reasons the count conducted for this assessment could be on the low side. For example the network could have been operating particularly well on this occasion or favourable weather conditions contributed to smoother throughput.

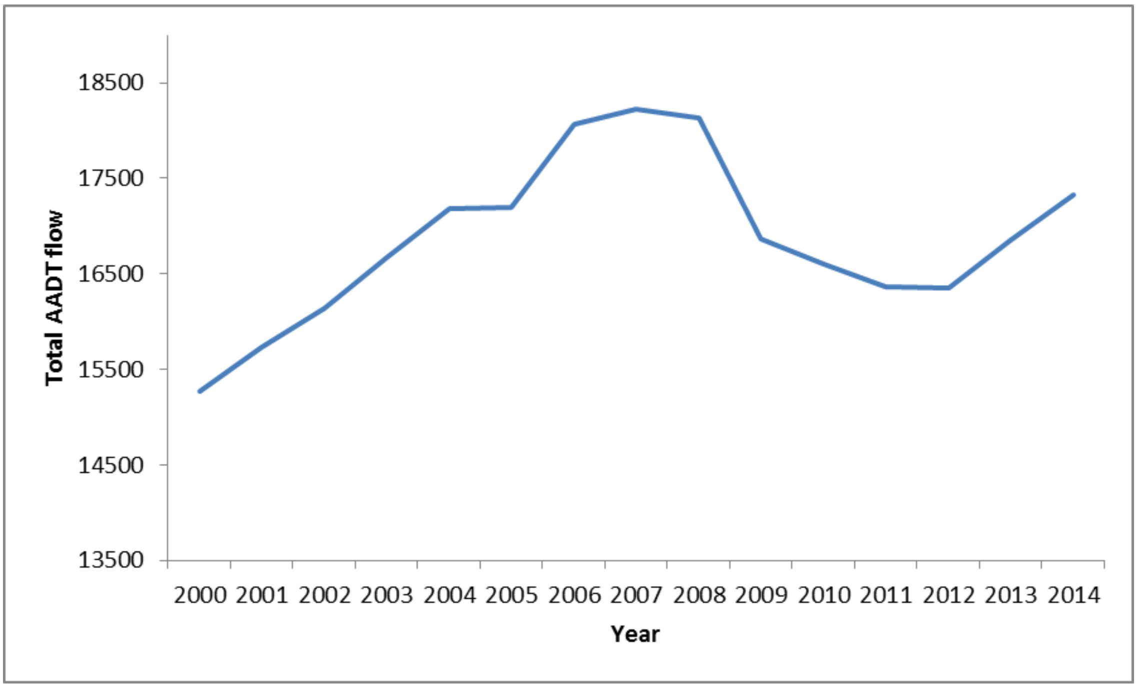


**Figure 11:** AADT flow data from the DfT count survey, Rugby Road Lutterworth

A comparison of breakdown by vehicle type from the DfT and the local ANPR survey is provided in Table 6. The data provides similar proportions and the overall light to heavy duty vehicle split is the same. However, there are fewer cars in the DfT count data and a higher proportion of LGVs. The differences may be due to the fact that the DfT's automatic traffic count is based on the length of vehicles as they pass and there may be some larger cars that have been classified as LGVs. It is also fair to say that under-road classification systems are not that reliable under low speed conditions.

**Table 6:** Comparison of fleet composition in Lutterworth from the ANPR and DfT surveys

| Data source | Percentage composition | | | | |
|---|---|---|---|---|---|
| | Car | LGV | Rigid HGV | Artic HGV | Bus |
| ANPR | 83.3% | 10.4% | 3.9% | 2.3% | 0.1% |
| DfT | 79.4% | 14.2% | 3.7% | 2.2% | 0.6% |

The National Atmospheric Emissions Inventory (NAEI) provides a breakdown of fleet composition in terms of European emission standards. These data are forecasted for each year to 2030 from earlier years. Typically, the NAEI predictions show that in 2016, it was expected that there would be a higher number of Euro 6 vehicles in the national fleet than actually observed on the road. Some examples of these differences can be seen in Figure 12 to Figure 14. The results of the survey also show the higher levels of older vehicles being retained in the fleet.

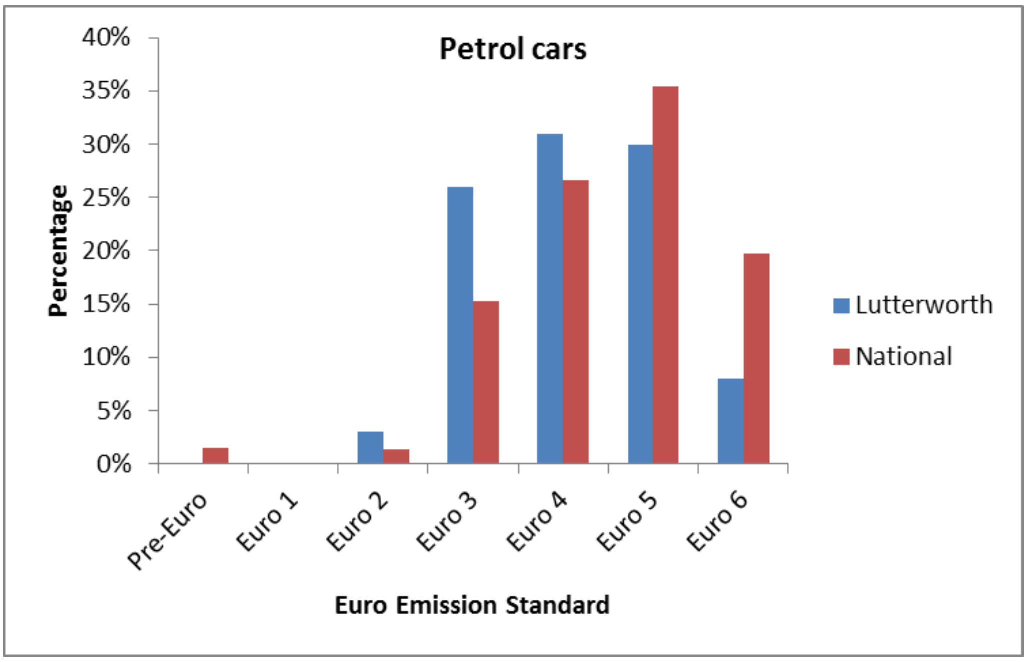


**Figure 12:** Comparison between proportion of Euro emission standard from national and local data, petrol cars in 2016

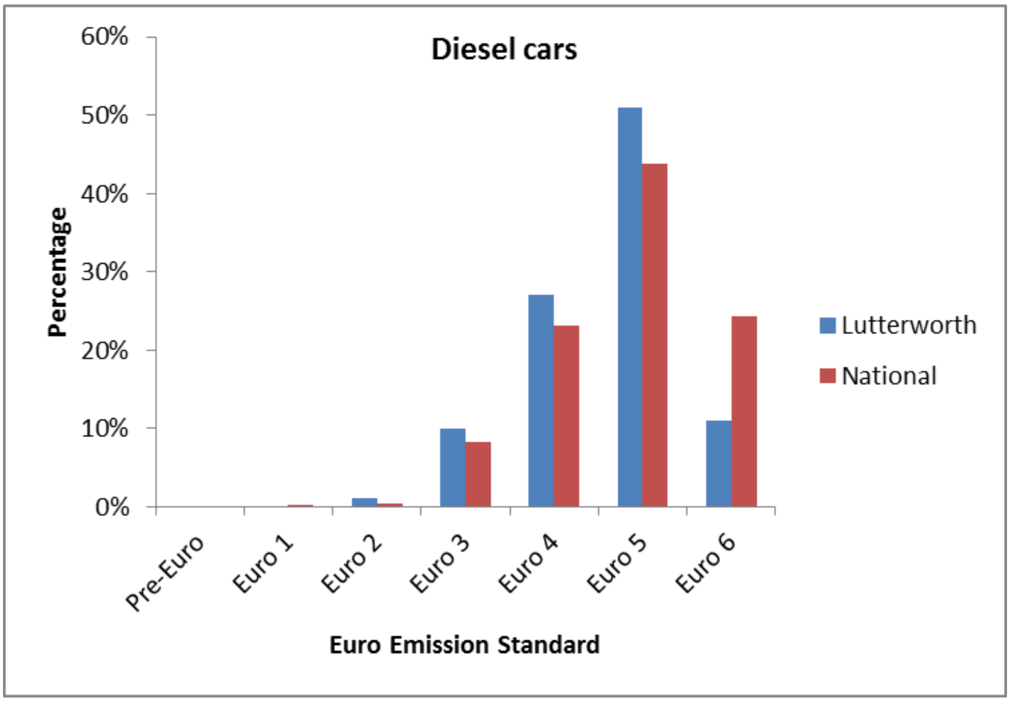


**Figure 13:** Comparison between proportion of Euro emission standard from national and local data, diesel cars in 2016

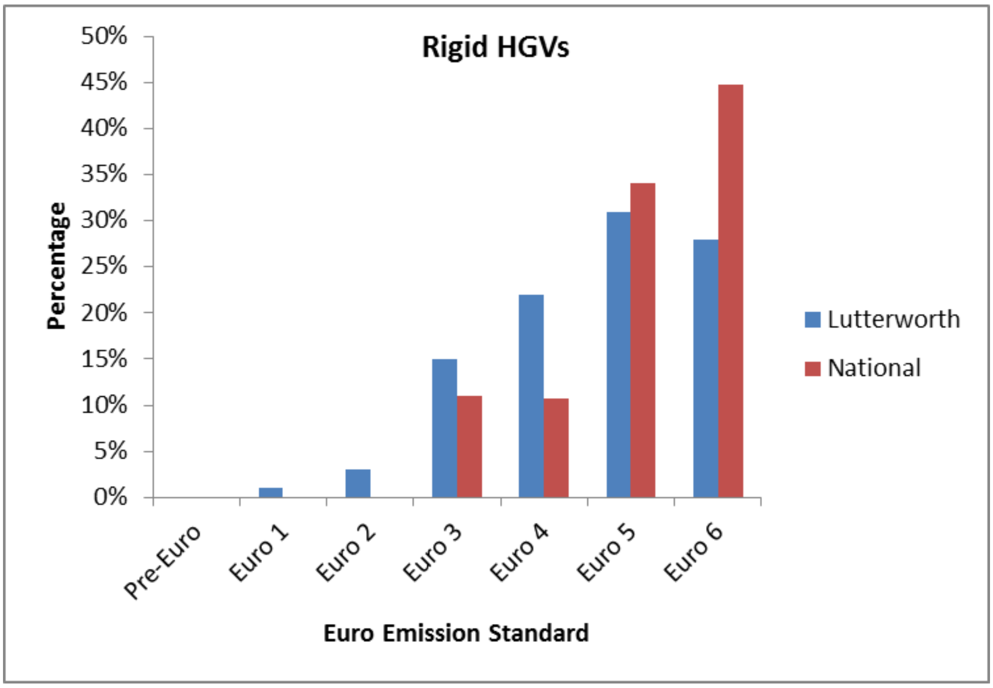


**Figure 14:** Comparison between proportion of Euro emission standard from national and local data, rigid diesel HGVs in 2016

## 3.2 Drive cycle statistics

A total of 69 drive cycle runs were conducted with 23 in the morning period (between 8am to 9.30am), 20 in the inter-peak (IP) period (between 12pm-1pm) and 26 in the afternoon peak (5pm to 7pm). In addition on the day there was an accident around 5.30-6.30pm on the roundabout to the south of Rugby Road, Lutterworth which caused traffic travelling southbound towards the roundabout to become heavily congested. These runs were treated separately in the analysis.

These drive cycle runs were broken down as given below:

- 30 mph limit northbound – 7 AM runs, 5 IP runs and 6 PM runs
- 20 mph limit northbound - 5 AM runs, 5 IP runs and 6 PM runs
- 30 mph limit southbound – 5 AM runs, 5 IP runs and 6 PM runs
- 20 mph limit southbound – 6 AM runs, 5 IP runs and 4 PM runs
- Congestion period southbound – 6 PM runs

The second-by-second data collected from these drive cycle runs were analysed to determine a number of parameters averaged by time period from start to finish of the runs (see route in Figure 4) over a distance of around 750 metres. These parameters included average and maximum speed, duration and the proportion of seconds spent idling, accelerating and decelerating. A summary of these statistics is given in Table 7 with the full set of results for each run provided in Appendix A.

The data presented in Table 7 shows the following observations:

- The average speed recorded was much lower than the existing 30 mph limit. Across all 30 mph drive cycle runs, the average speed was just 28.9 km/h which is already below a 20 mph speed limit (i.e. 18 mph). However, the maximum speed recorded was closer to the speed limit at 45 km/h (28 mph).
- The average speed recorded when simulating the effect of a 20 mph limit was lower still at 24.5 km/h (15 mph). The maximum speed was lower than the 30 mph drive cycle runs, but in the northbound direction this was above the tested limit at 43 km/h (27 mph). In the southbound direction, the maximum speed recorded of 35 km/h (22 mph) was just over the limit.
- The proportion of time spent driving between 20-30 mph in the current 30 mph limit was on average around 50 percent with the remaining time spent at speeds below 20 mph (see Figure 15). During the congested afternoon period in the southbound direction, the vehicle did not reach speeds above 20 mph (32 km/h). When simulating a 20 mph limit, the vehicle spent between 85-95 percent of the time at speeds lower than this limit which meant there were some situations where the driver found it difficult to remain below the simulated speed limit (see Figure 16).
- The traffic was actually found to be busiest in the inter-peak period in both directions, meaning that the travel time and idle time were higher and average speed was lower than both the morning and afternoon peak times. This is often systematic of lunchtime traffic combining with business related traffic.
- Due to the accident at the roundabout, the traffic took on average 6 minutes to travel in the southbound direction (compared to typically 1-2 minutes) with an average speed during this time of just 7 km/h. 25 percent of the time on these runs was spent idling was in contrast to an idle time of around 5 percent during typical traffic conditions (see Table 7 and Figure 17). The results indicate that in general the traffic moves fairly consistently through the system.

**Table 7:** Summary statistics of drive cycle runs

| Direction | Period | Average time (min) | Average speed (km/h) | Max speed (km/h) | % idle time | % acceleration time | % deceleration time |
|---|---|---|---|---|---|---|---|
| 30 mph (48 km/h) | | | | | | | |
| North-bound | AM | 00:01:34 | 29.9 | 44.8 | 4% | 43% | 53% |
| North-bound | IP | 00:01:58 | 26.7 | 44.5 | 5% | 46% | 49% |
| North-bound | PM | 00:01:39 | 29.7 | 45.4 | 3% | 44% | 52% |
| South-bound | AM | 00:01:35 | 30.1 | 45.3 | 4% | 53% | 42% |
| South-bound | IP | 00:02:05 | 23.6 | 43.7 | 10% | 50% | 41% |
| South-bound | PM | 00:01:24 | 33.2 | 44.4 | 4% | 49% | 47% |

| Direction | Period | Average time (min) | Average speed (km/h) | Max speed (km/h) | % idle time | % acceleration time | % deceleration time |
|---|---|---|---|---|---|---|---|
| 20 mph (32 km/h) | | | | | | | |
| North-bound | AM | 00:02:05 | 24.1 | 39.0 | 5% | 46% | 49% |
| North-bound | IP | 00:02:09 | 23.4 | 43.8 | 8% | 42% | 50% |
| North-bound | PM | 00:01:43 | 28.1 | 42.2 | 5% | 44% | 51% |
| South-bound | AM | 00:02:06 | 23.0 | 33.6 | 4% | 55% | 41% |
| South-bound | IP | 00:02:18 | 20.5 | 35.1 | 9% | 50% | 41% |
| South-bound | PM | 00:01:40 | 28.1 | 34.5 | 2% | 50% | 48% |
| Congestion | | | | | | | |
| South-bound | PM | 00:06:39 | 7.2 | 28.9 | 25% | 36% | 38% |

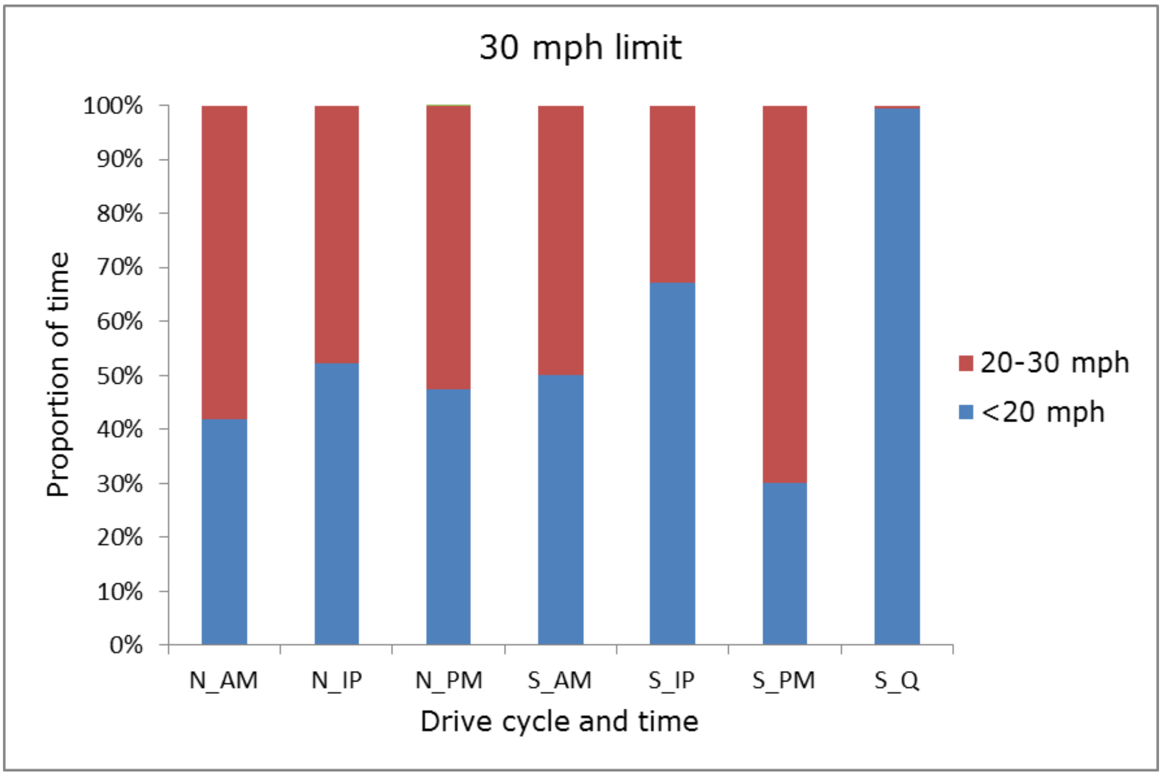


**Figure 15:** Proportion of time spent at different speeds, 30 mph speed limit

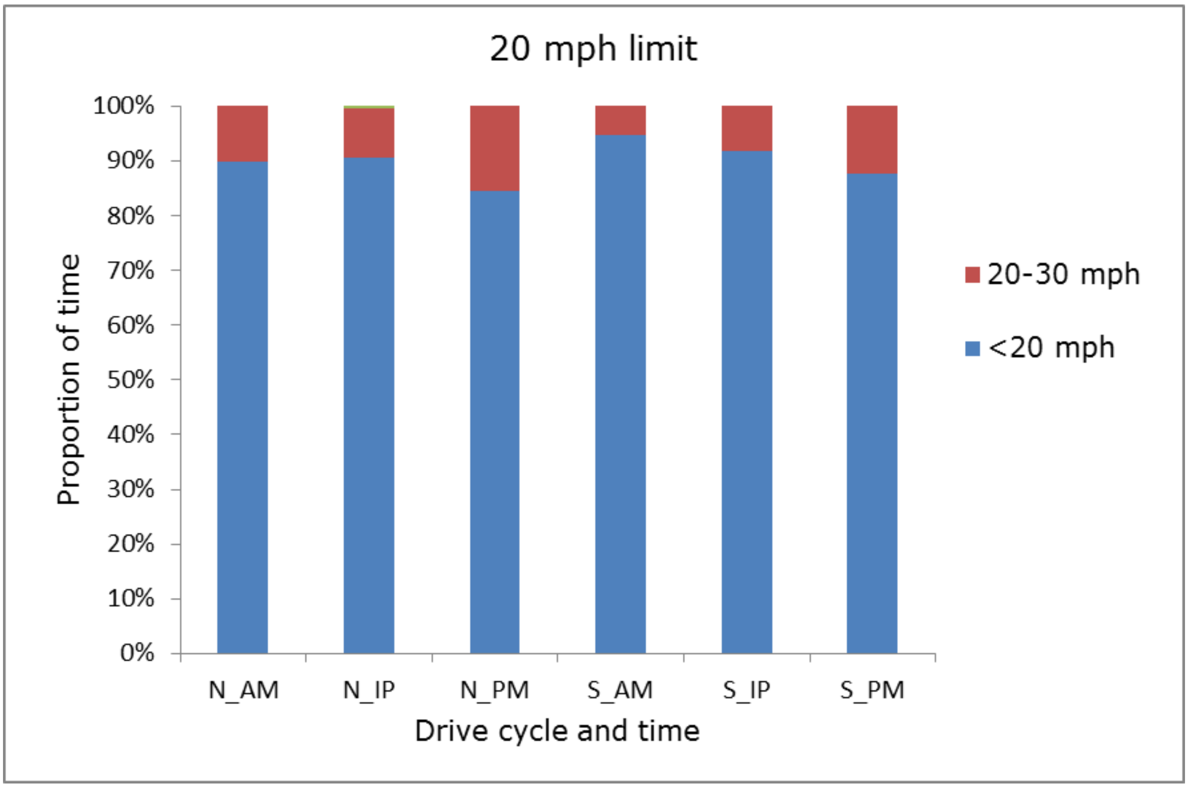


Figure 16: Proportion of time spent at different speeds, 20 mph speed limit

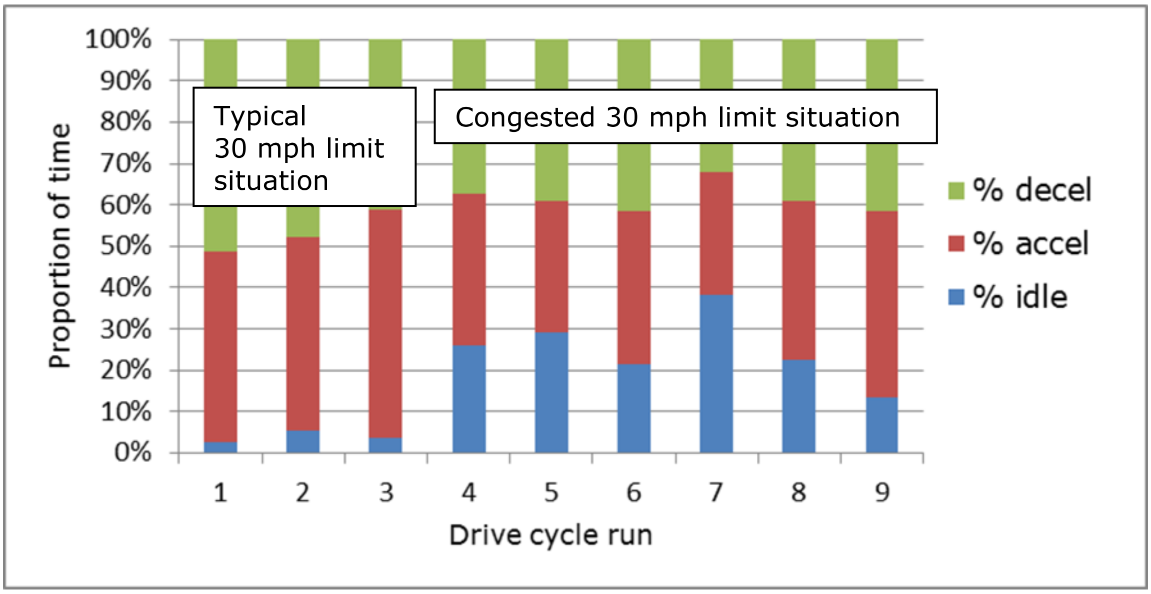


Figure 17: Proportion of time spent idling, accelerating and decelerating, southbound direction in afternoon peak period

Further analysis was conducted to further consider acceleration events which are considered to be one of the main influences on emissions. The key parameters in this case were standard deviation of the instantaneous speed, the average positive acceleration (APA) and the relative positive acceleration (RPA). The summary results of this analysis are given in Table 8.

The standard deviation of vehicle speed provides an indication of how much the speed has deviated from the mean speed of any given driving cycle recorded by the study. The APA indicates the average rate of acceleration in metres per second squared across the driving cycle and the RPA is calculated as the integral of the product of instantaneous speed and instantaneous positive acceleration over the driving cycle such as:

$$RPA = \frac{\int_0^{t_j} (v_i \times a_i)dt}{x_j}$$

Where: *t*j = time

*x*j = distance of drive cycle *j*

*v*i = speed during each increment *i*

*a*i = instantaneous positive acceleration during each increment *i* contained in the driving cycle *j*

**Table 8:** Summary data on positive acceleration

| Speed limit | Average positive acceleration ($m/s^2$) | Relative positive acceleration ($m/s^2$) | Average standard deviation (km/h) |
|---|---|---|---|
| 30 mph NB | 0.41 | 0.17 | 12 |
| 20 mph NB | 0.32 | 0.13 | 8 |
| Difference (%) | -21% | -20% | -29% |
| 30 mph SB | 0.49 | 0.23 | 13 |
| 20 mph SB | 0.34 | 0.17 | 8 |
| Difference (%) | -31% | -28% | -30% |
| Congestion | 0.38 | 0.21 | 7 |

The standard deviation of instantaneous speed provides the confidence that driving cycles were undertaken that best represent both 30 mph and 20 mph situations. At the lower speed limit the deviation was 8 km/h in the south and northbound directions. A standard deviation of 7 km/h was recorded under congested conditions in the southbound direction only.

Typical values for APA at 30 mph in the north and southbound directions range between 0.4-0.5 $m/s^2$. For reference the typical value you might expect under laboratory conditions across the New European Drive Cycle (NEDC) would be 0.5 m/s (Barlow *et al.*, 2009). For the 20 mph limit APA reduces to within the range of 0.3-0.35 $m/s^2$. This represents a percentage reduction of 21 and 31 percent respectively. Similar reductions were also observed for RPA, the typical range recorded being between 0.17 $m/s^2$ and 0.23 $m/s^2$. Again, a typical value across the NEDC would be 0.11 $m/s^2$. In this case the percentage reduction in the north and southbound directions was 20 and 28 percent respectively.

Figure 18 provides a plot of the average RPA calculated for each driving cycle ranked in ascending order by speed limit and travel direction. The plot excludes the afternoon driving cycles under heavily congested conditions. It is clear that higher acceleration events are evident in the southbound direction and that under a 20 mph speed limit where the average speed was lower the overall relative acceleration is reduced.

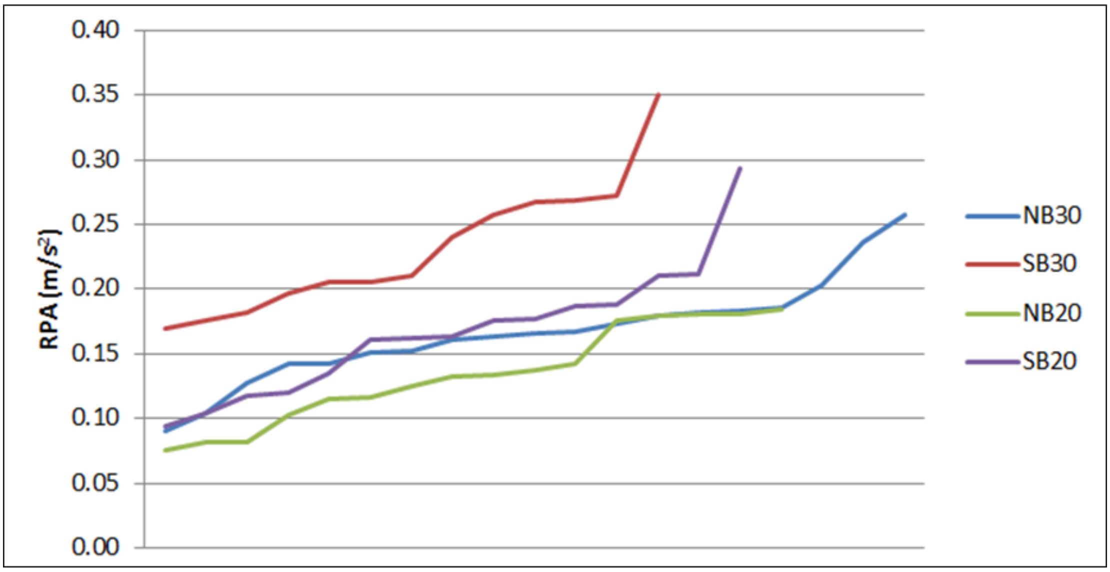


Figure 18: Relative positive acceleration results in 30 mph and 20 mph speed limits (not including congested driving cycles)

It is worth noting that speeds were logged at one second intervals. It is possible that by increasing the logging intervals to 0.5 seconds or 0.1 seconds would capture more acceleration peaks[5]. Under these conditions emissions are likely to be higher than those estimated by PHEM (over one second intervals). The APA and RPA results for this study can be considered to be on the conservative side.

[5] H Bratt and E Ericsson (2000) Measuring vehicle driving patterns – estimating the influence of different measuring intervals. Department of Technology and Society Division of Traffic Planning Lund Institute of Technology Lund University

## 3.3 Emissions

Following the methodology set out in Section 2.2.2, light duty and heavy duty emissions rates (in g/km/s) were calculated for $NO_x$, PM and $CO_2$ for each individual run and then summed for each run. Averages from the individual runs were determined by direction of travel and by driving style. Overall, the light duty vehicles (i.e. cars and vans) which make up 94 percent of the traffic flow were responsible for around 45 percent of $NO_x$ emissions, 70 percent of $PM_{10}$ emissions and the vast majority of $CO_2$ emissions (75-80 percent).

To consider the impact of introducing a 20 mph speed limit, a summary of the average emissions are given in Table 9 in terms of grammes pollution emitted per km of the entire drive cycle route for each of the periods. These rates were converted to emission rates based on the north and southbound traffic flow over the day and these are provided in Table 10 with the average change from 30 to 20 mph given as a percentage in Table 11.

Although there are some variations in the results between individual runs and time of day, the analysis shows that on average the impact of introducing a 20 mph speed limit to replace the existing 30 mph speed limit along this route has the potential to reduce emissions of NOx, PM and $CO_2$ by between 3-6 percent with an average of around 5 percent. Results from the individual drive cycle runs are provided in Appendix B.

It is noted that the impact of the accident in the afternoon period on journey times, average speeds and emissions is much more pronounced than the impact of reducing the speed limit. For example, the result of this accident meant that traffic in the southbound direction took on average 6 times as long to travel along the route. The average speed was reduced to just 7 km/h with 25 percent of time spent idling (i.e. stationary). The impact of this resulted in much higher emissions of between 77-88 percent compared to typical driving conditions.

**Table 9:** Summary statistics and average emissions across drive cycle runs

| Direction | Period | Average time (min) | Average speed (km/h) | Max speed (km/h) | LDV NOx (g/km) | LDV PM (g/km) | LDV $CO_2$ (g/km) | HDV NOx (g/km) | HDV PM (g/km) | HDV $CO_2$ (g/km) |
|---|---|---|---|---|---|---|---|---|---|---|
| 30 mph (48 km/h) | | | | | | | | | | |
| North-bound | AM | 00:01:34 | 29.9 | 44.8 | 0.23 | 0.011 | 163.6 | 4.48 | 0.079 | 824.4 |
| North-bound | IP | 00:01:58 | 26.7 | 44.5 | 0.26 | 0.013 | 185.7 | 5.13 | 0.095 | 936.2 |
| North-bound | PM | 00:01:39 | 29.7 | 45.4 | 0.23 | 0.013 | 169.7 | 4.74 | 0.085 | 843.4 |
| South-bound | AM | 00:01:35 | 30.1 | 45.3 | 0.28 | 0.014 | 192.0 | 5.72 | 0.098 | 1045.2 |
| South-bound | IP | 00:02:05 | 23.6 | 43.7 | 0.33 | 0.016 | 224.4 | 6.41 | 0.116 | 1259.8 |
| South-bound | PM | 00:01:24 | 33.2 | 44.4 | 0.27 | 0.014 | 186.4 | 5.49 | 0.090 | 1018.3 |

| 20 mph (32 km/h) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| North-bound | AM | 00:02:05 | 24.1 | 39.0 | 0.24 | 0.013 | 179.3 | 4.79 | 0.088 | 816.5 |
| North-bound | IP | 00:02:09 | 23.4 | 43.8 | 0.24 | 0.012 | 175.4 | 4.74 | 0.087 | 818.4 |
| North-bound | PM | 00:01:43 | 28.1 | 42.2 | 0.20 | 0.011 | 153.4 | 4.37 | 0.074 | 648.4 |
| South-bound | AM | 00:02:06 | 23.0 | 33.6 | 0.27 | 0.014 | 199.7 | 5.58 | 0.102 | 973.5 |
| South-bound | IP | 00:02:18 | 20.5 | 35.1 | 0.31 | 0.015 | 218.9 | 6.19 | 0.115 | 1096.3 |
| South-bound | PM | 00:01:40 | 28.1 | 34.5 | 0.23 | 0.012 | 166.7 | 5.04 | 0.082 | 784.7 |
| Congestion | | | | | | | | | | |
| South-bound | PM | 00:06:39 | 7.2 | 28.9 | 0.51 | 0.021 | 393.2 | 9.68 | 0.219 | 1722.4 |

**Table 10:** Average emissions for the north and southbound direction in different conditions

| Direction of travel | Average emission rates (g/km/s) | | |
|---|---|---|---|
| | NOx | PM | $CO_2$ |
| Northbound 30 mph | 0.047 | 0.002 | 19.49 |
| Northbound 20 mph | 0.045 | 0.001 | 18.51 |
| Southbound 30 mph | 0.056 | 0.002 | 21.95 |
| Southbound 20 mph | 0.052 | 0.002 | 20.98 |
| Southbound 30 mph congestion | 0.099 | 0.003 | 41.34 |

**Table 11:** Modelled average change in speed and emissions from introducing a 20 mph speed limit to a 30 mph

| Direction of travel | Average change in speed (km/h) | Average percentage change in emissions from 30 mph speed limit to 20 mph limit | | |
|---|---|---|---|---|
| | | NOx | PM | $CO_2$ |
| Northbound | -3.6 | -4.6% | -3.6% | -5.0% |
| Southbound | -5.1 | -6.3% | -3.1% | -4.4% |

## 3.4 Concentrations

### 3.4.1 *Model verification*

$NO_2$ concentrations at the roadside diffusion tube sites are given in Table 12 and results of the model verification at these sites are provided in Figure 19 and Table 13. The model under-predicted road $NO_x$ concentrations at all monitoring sites by an average of 34 percent which meant that the outputs had to be adjusted. A factor of 1.5439 was applied to all results according to the relationship in Figure 19. Based on Defra's calculator tool, the resulting modelled $NO_2$ concentrations were within 15 percent of the measured concentrations which is considered to be a relatively good agreement. The model over-predicted concentrations at some sites and under-predicted at others - typically, those sites on the west side of the High Street (i.e. sites 24 and 26n) as the prevailing wind direction used in the model was from the south-west.

**Table 12:** Diffusion tube monitoring site locations and 2015 concentrations (bias adjusted).

| Site ID | OS grid reference (x,y) | | Tube height (m) | Distance to kerb (m) | Measured $NO_2$ (µg/m$^3$) | Measured road $NO_x$( µg/m$^3$)[6] |
|---|---|---|---|---|---|---|
| 01n | 454475 | 284560 | 2 | 4 | 44.6 | 58.9 |
| 18n | 454443 | 284348 | 2 | 3 | 38.4 | 43.7 |
| 23n | 454428 | 284274 | 2 | 2.5 | 29.6 | 23.9 |
| 24n | 454410 | 284326 | 2 | 4 | 49.0 | 70.2 |
| 25n | 454497 | 284618 | 2 | 5 | 35.2 | 36.3 |
| 27n | 454476 | 284178 | 2 | 5 | 33.1 | 31.6 |
| 26n | 454432 | 284229 | 2 | 2 | 41.6 | 51.4 |

**Table 13:** Results of model verification against diffusion tube sites

| Site ID | Annual mean concentrations (µg/m$^3$) | | | | | % Difference between modelled/ measured $NO_2$ |
|---|---|---|---|---|---|---|
| | Measured road $NO_x$ | Modelled road $NO_x$ | Adjusted modelled road $NO_x$ | Modelled $NO_2$ | Measured $NO_2$ | |
| 01n | 58.9 | 47.7 | 73.6 | 50.3 | 44.6 | 11% |
| 18n | 43.7 | 24.3 | 37.5 | 35.7 | 38.4 | -8% |
| 23n | 23.9 | 22.8 | 35.2 | 34.7 | 29.6 | 15% |
| 24n | 70.2 | 35.2 | 54.4 | 42.8 | 49.0 | -14% |
| 25n | 36.3 | 24.4 | 37.7 | 35.8 | 35.2 | 2% |
| 27n | 31.6 | 19.2 | 29.6 | 32.2 | 33.1 | -3% |
| 26n | 51.4 | 27.4 | 42.4 | 37.8 | 41.6 | -10% |

[6] From Defra's NOx-$NO_2$ calculator v5.1 at http://laqm.defra.gov.uk/review-and-assessment/tools/background-maps.html#NOXNO2calc

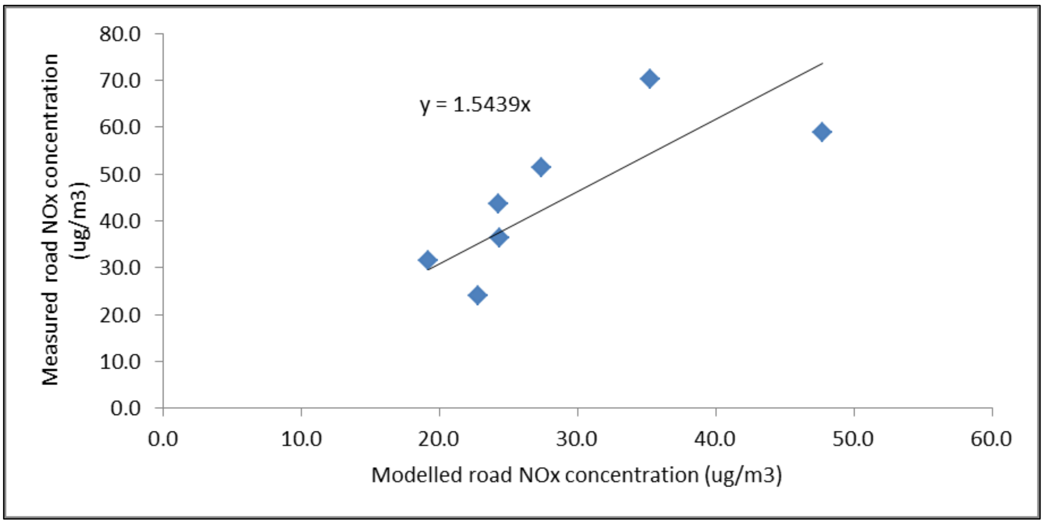


**Figure 19:** Relationship between modelled and measured road $NO_x$ concentrations

### *3.4.2 Modelled concentrations*

The results of the modelled annual mean $NO_2$ concentrations at individual receptors at the façade of houses (as indicated in Figure 7) are given in Table 14 for the 30 mph existing base situation and 20 mph scenario. The change due to the 20 mph speed limit is also shown compared to the base and the overall population weighted concentrations are provided.

**Table 14:** Modelled annual mean $NO_2$ concentration at receptors and change due to 20 mph speed limit zone

| No. | Address | Estimated number of people in building[7] | Annual mean $NO_2$ concentration (µg/m$^3$) | | |
|---|---|---|---|---|---|
| | | | 30 mph base | 20 mph scenario | Difference from base |
| 1 | 32 Market Street | 2.1 | 31.9 | 30.5 | -1.4 |
| 2 | 3 Walker-Manor Court | 2.1 | 25.7 | 25.3 | -0.4 |
| 3 | 2 Walker-Manor Court | 2.1 | 26.0 | 25.6 | -0.4 |
| 4 | 30 Market Street | 2.1 | 31.4 | 30.9 | -0.5 |
| 5 | 28 Market Street, Walker-Manor Court | 4.2 | 31.2 | 31.1 | -0.1 |
| 6 | 26 Market Street | 2.1 | 31.9 | 31.9 | 0.0 |
| 7 | 1 Walker-Manor Court | 2.1 | 28.6 | 28.7 | 0.1 |
| 8 | 24 Market Street | 2.1 | **40.1** | **40.5** | 0.3 |
| 9 | 12 Walker-Manor Court | 2.1 | 28.0 | 28.1 | 0.1 |
| 10 | 22 Market Street | 2.1 | **50.4** | **51.6** | 1.2 |
| 11 | 20 Market Street | 2.1 | **49.1** | **50.2** | 1.1 |
| 12 | 25 Market Street | 2.1 | **51.6** | **52.9** | 1.3 |
| 13 | 23 Market Street | 2.1 | **52.9** | **54.3** | 1.4 |
| 14 | 29 Market Street | 2.1 | 24.8 | 24.8 | 0.1 |
| 15 | 18 Market Street | 2.1 | 34.5 | 34.9 | 0.4 |

[7] 2.1 people per household based on UK census data for Lutterworth Springs Ward

| No. | Address | Estimated number of people in building[7] | Annual mean $NO_2$ concentration (µg/m$^3$) | | |
|---|---|---|---|---|---|
| | | | 30 mph base | 20 mph scenario | Difference from base |
| 16 | 16 Market Street | 2.1 | **48.4** | **49.4** | 1.0 |
| 17 | 17/17a Market Street | 4.2 | **50.5** | **51.7** | 1.1 |
| 18 | 15/15A Market Street | 4.2 | **50.8** | **51.9** | 1.1 |
| 19 | 11 Market Street | 2.1 | **46.9** | **48.3** | 1.4 |
| 20 | Manor House 14 Market Street | 2.1 | **49.4** | **50.4** | 0.9 |
| 21 | The Old Chapel, Chapel Street | 2.1 | 21.2 | 21.1 | -0.2 |
| 22 | Flat The Greyhound 9 Market Street | 2.1 | **52.8** | **53.9** | 1.1 |
| 23 | 7 Market Street | 2.1 | **54.9** | **55.7** | 0.8 |
| 24 | 10 - 12, 12, 12B, 12C | 12.6 | 28.9 | 28.6 | -0.3 |
| 25 | Barn Rear Of 12 Market Street | 2.1 | 25.3 | 25.1 | -0.3 |
| 26 | 10A, Flat 1 and Flat 2 10 Market Street | 6.3 | 25.4 | 24.6 | -0.7 |
| 27 | 10 - 12 Bell Street | 6.3 | 27.4 | 25.9 | -1.5 |
| 28 | 4 Shambles Court Bell Street | 2.1 | 22.2 | 21.7 | -0.5 |
| 29 | 3 Shambles Court Bell Street | 2.1 | 21.6 | 21.1 | -0.5 |
| 30 | 5 Market Street | 2.1 | **50.7** | **51.3** | 0.6 |
| 31 | 3 Market Street | 2.1 | **55.9** | **55.9** | 0.0 |
| 32 | 1A Market Street | 2.1 | 26.8 | 25.8 | -1.0 |
| 33 | 1, 1C Market Street | 4.2 | 45.1 | 38.3 | -6.8 |
| 34 | 1E Market Street | 2.1 | 28.9 | 26.5 | -2.4 |
| 35 | 1B Market Street | 2.1 | 29.5 | 26.9 | -2.6 |
| 36 | 4A Church Street | 2.1 | 30.3 | 27.4 | -2.9 |
| 37 | 6A Church Street | 2.1 | 23.5 | 22.4 | -1.1 |
| 38 | 4 , 4A High Street | 4.2 | 32.6 | 29.3 | -3.3 |
| 39 | 3, 3A Church Street | 4.2 | 26.3 | 24.5 | -1.9 |
| 40 | 6, 6A High Street | 4.2 | **45.6** | **40.1** | -5.5 |
| 41 | 8C, 8D High Street | 4.2 | **45.7** | **40.2** | -5.6 |
| 42 | 7 The Hind Mews, 8 High St | 2.1 | 26.3 | 24.5 | -1.9 |
| 43 | 8A, 8B, 10C High Street | 6.3 | **48.2** | **42.2** | -6.0 |
| 44 | 6 The Hind Mews | 2.1 | 25.1 | 23.6 | -1.5 |
| 45 | 10, 10A, 10B High Street | 6.3 | **45.6** | **40.1** | -5.5 |
| 46 | Flat 1,2, 3 12 High St, 12 High Street | 8.4 | **45.2** | 39.8 | -5.4 |
| 47 | 14, 14A, 14B, 14D High Street | 8.4 | **45.2** | 39.9 | -5.3 |
| 48 | 16B High Street | 2.1 | **45.6** | **40.3** | -5.3 |
| 49 | 18 High Street, Flat 1, 2, 3 18 High St | 8.4 | **48.6** | **43.0** | -5.6 |
| 50 | 20 High Street | 2.1 | **46.6** | **41.6** | -4.9 |
| 51 | 22, 22b, Flat 1, Flat 2 22 High Street | 8.1 | **46.8** | **42.2** | -4.6 |
| 52 | 19A, 19B, 21 High Street | 6.3 | **40.3** | 34.7 | -5.6 |
| 53 | Flat 17, 17B High Street | 4.2 | 35.4 | 31.2 | -4.2 |
| 54 | 15A, Flat 1 and 2 15A High | 6.3 | 35.1 | 30.9 | -4.1 |

| No. | Address | Estimated number of people in building[7] | Annual mean $NO_2$ concentration (µg/$m^3$) | | |
|---|---|---|---|---|---|
| | | | 30 mph base | 20 mph scenario | Difference from base |
| | Street | | | | |
| 55 | 13, 13A, 15 High Street | 6.3 | 34.6 | 30.6 | -4.0 |
| 56 | 9, Flat 1, 2 9 High St, Flat 11-13, High Street | 10.5 | 34.2 | 30.2 | -3.9 |
| 57 | 7, First floor front, first floor Rear 7 High Street | 6.3 | 25.7 | 23.9 | -1.8 |
| 58 | First Floor And Second Floor 19 High Street | 4.2 | 27.4 | 25.3 | -2.1 |
| 59 | 1 Misterton Way, Lonsdale House, First floor Lonsdale House | 6.3 | **44.3** | 38.4 | -6.0 |
| 60 | 27, 27A, 27B High Street | 6.3 | 36.9 | 35.7 | -1.2 |
| 61 | 31, 31A, 31B High Street | 6.3 | 36.5 | 35.8 | -0.8 |
| 62 | 31C High Street Lutterworth | 2.1 | 26.9 | 26.6 | -0.3 |
| 63 | 33A, 33B ,33C, First and 2nd floor 33 High Street | 10.5 | 37.6 | 37.0 | -0.6 |
| 64 | 35 High Street | 2.1 | 38.2 | 37.6 | -0.6 |
| 65 | 37, Ground, First and 2nd Floor High Street | 6.3 | **48.2** | **48.4** | 0.2 |
| 66 | 39 High Street | 2.1 | **41.7** | **40.8** | -0.8 |
| 67 | 41, Flat 41-43 High Street | 8.4 | **50.2** | **50.4** | 0.2 |
| 68 | 45 High Street | 2.1 | 39.4 | 38.4 | -1.0 |
| 69 | 47 High Street | 2.1 | 37.5 | 36.5 | -1.0 |
| 70 | 6 The Terrace Rugby Road | 2.1 | 34.2 | 34.0 | -0.3 |
| 71 | Regent Court Regent Street | 2.1 | **46.3** | **48.0** | 1.7 |
| 72 | 10,12,13,14,15,16,18,20,21 Regent Court Regent Street | 18.9 | 23.1 | 23.1 | 0.0 |
| 73 | 4,5,6,7,8,9 Regent Court Regent Street | 12.6 | 25.7 | 25.8 | 0.1 |
| 74 | 1,2,3 Regent Court Regent Street | 6.3 | 27.3 | 27.3 | 0.0 |
| 75 | 1,2,4,5,8,9 Denbigh Court | 12.6 | 31.3 | 31.4 | 0.2 |
| 76 | 23,24,3,7 Denbigh Court | 8.4 | 32.0 | 31.3 | -0.7 |
| 77 | Flat, The Springs Stoney Hollow | 2.1 | 39.2 | 39.8 | 0.6 |
| 78 | The Coach House Rugby Road | 2.1 | **39.6** | **40.2** | 0.6 |
| 79 | Dale House Regent Street | 2.1 | 21.0 | 21.0 | 0.0 |
| 80 | 1 Rugby Road | 2.1 | 26.8 | 26.8 | 0.0 |
| 81 | 22 Riverside Road | 2.1 | 26.0 | 25.9 | 0.0 |
| 82 | 17 Rugby Road | 2.1 | 27.0 | 26.9 | -0.1 |
| 83 | 15 Rugby Road | 2.1 | 27.7 | 27.7 | 0.0 |
| 84 | 13 Rugby Road | 2.1 | 26.3 | 26.2 | 0.0 |
| 85 | 11 Rugby Road | 2.1 | 27.4 | 27.4 | 0.0 |
| 86 | 9 Rugby Road | 2.1 | 27.1 | 27.0 | 0.0 |

| No. | Address | Estimated number of people in building[7] | Annual mean $NO_2$ concentration (µg/m$^3$) | | |
|---|---|---|---|---|---|
| | | | 30 mph base | 20 mph scenario | Difference from base |
| 87 | 7 Rugby Road | 2.1 | 27.4 | 27.3 | 0.0 |
| 88 | 5 Rugby Road | 2.1 | 27.7 | 27.7 | 0.0 |
| 89 | 3 Rugby Road | 2.1 | 27.3 | 27.3 | 0.0 |
| 90 | Wood Bank Rugby Road | 2.1 | 24.4 | 24.4 | 0.1 |
| 91 | 28 Rugby Road | 2.1 | 22.9 | 23.0 | 0.1 |
| 92 | 34 Rugby Road | 2.1 | **41.6** | **42.3** | 0.7 |
| Population weighted concentration | | 371.4 | 13,267.2 | 12,658.11 | -609.09 (-5%) |

The modelling results show that there are a number of properties predicted to have annual mean $NO_2$ concentrations above the annual mean objective of 40 µg/m$^3$. These values are given in bold in Table 14. Overall the results show that there is an average of **1.2 µg/m$^3$ (3 percent) reduction** across all receptors with a maximum reduction of 6.8 µg/m$^3$ (15 percent) and maximum increase of 1.7 µg/m$^3$ (4 percent) at selected receptors. These modelled increases are mainly found at receptors to the north of Market Street where concentrations are already well above the annual mean objective. There are a few smaller increases predicted at a limited number of properties along Rugby Road. These properties are located along sections of the road with the steepest gradients. It's worth noting that the PHEM instantaneous emissions tool simulates different emissions for different gradients. In other words, it estimates increased emissions on inclines and decreasing emissions on declines. An increase in emissions is the result of higher demand being placed on engines to overcome the resistance of a gradient. Equally, emissions reduce on a decline because of the lower engine demand. For certain gradients the increase in emission owing to the incline is offset by the reduction in emissions caused by the decline. However, there are circumstances where this ratio is not in equilibrium depending on the traffic situation.

Conversely, the reductions in concentrations are found in the majority of the properties along the main High Street with some properties seeing a reduction that takes the concentration to below the objective (e.g. 19A, 19B, 21 High Street).

In total, the model was run at 92 receptors representing an estimated population of approximately 371 people in the modelled area. To determine the net effect on air quality the population weighted concentration was determined across all receptors. The concentration at each receptor was multiplied by the number of occupants for both the 30 mph base and 20 mph scenario. The results are provided in Table 14 which also shows the net change. Overall, the modelling predicts a **net reduction in the population weighted $NO_2$ annual mean concentration of 5 percent** across the modelled area.

The model was also run across a grid to produce contour plots for both annual mean $NO_2$ and $PM_{10}$. The resolution of the grid was increased perpendicular to all road emission sources using the ADMS intelligent gridding utility. The maximum distance between north and south grid points was ~18m and east to west ~7m which is sufficiently sensitive for the visual analysis of this study area. The results are presented in Figure 20 and Figure 21 for $NO_2$ and $PM_{10}$ respectively. Figure 20 shows the results for the base and scenario situation. Yellow is the key coloured contour as this represents the $NO_2$ annual mean objective of 40 µg/m$^3$. Accounting for the noise inherent in the modelling it would be recommended to consider the green banding as being locations of likely exceedance potential. Studying the colour maps it is clear that the red and orange areas reduce with a 20 mph limit imposed. The extent of the yellow and green contours estimated for the 20 mph speed limit shows that whilst the measure has not solved the problem it has certainly improved the air quality around the High Street. In accordance with the independent receptor results shown in Table 14 the colour maps confirm the impact of the Rugby Road to be negligible.

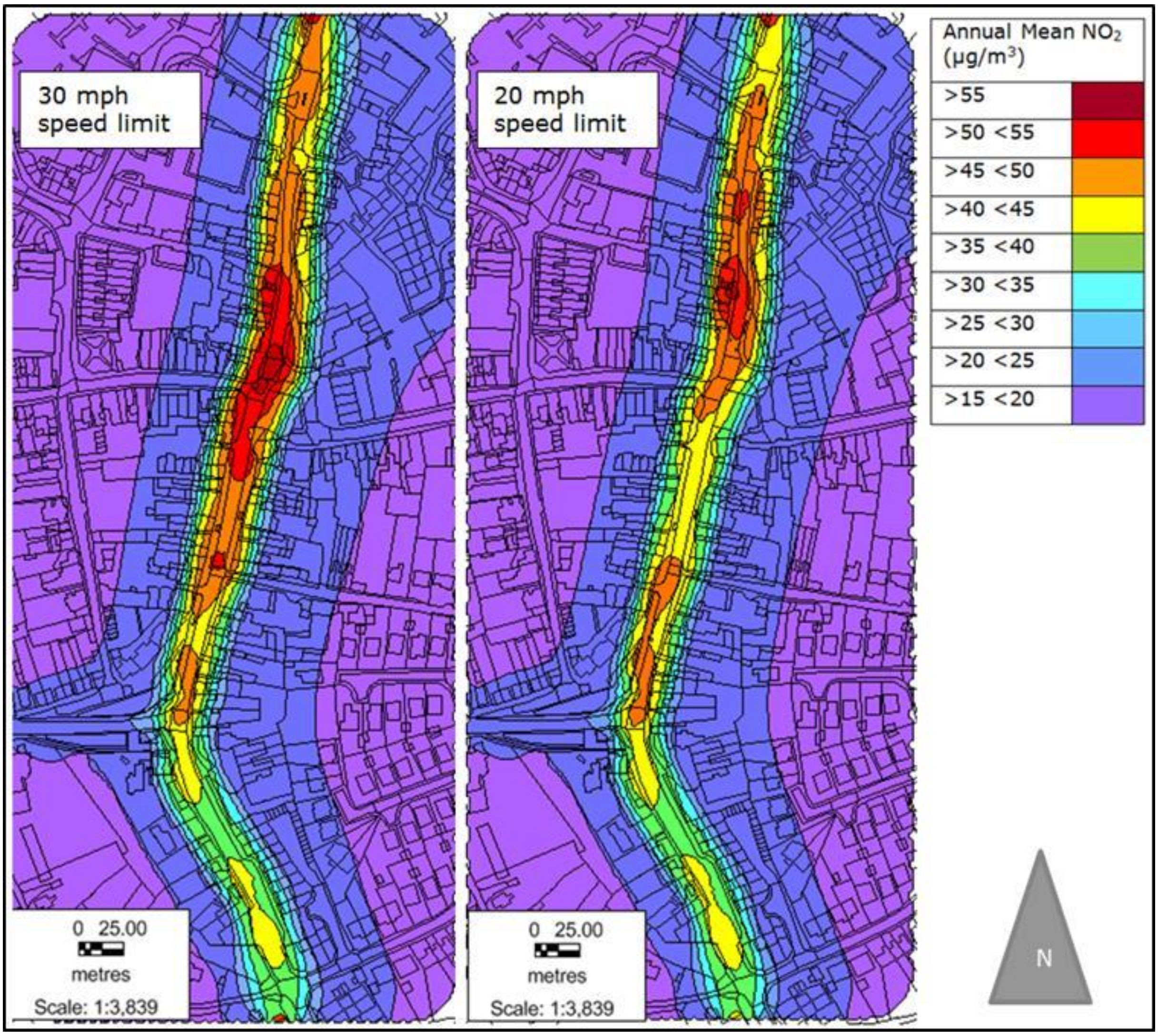


Figure 20. Annual mean $NO_2$ concentration contours for 30 and 20 mph speed limit

A contour map for annual mean $PM_{10}$ only is show in Figure 21. This is because air quality is meeting the annual mean objective at this location (i.e. below 40 µg/m$^3$). The maximum concentration is estimated to be below half of the objective value. It's worth noting that according to the results of the study were a 20 mph speed limited to be imposed the overall impact on PM would be reduced.

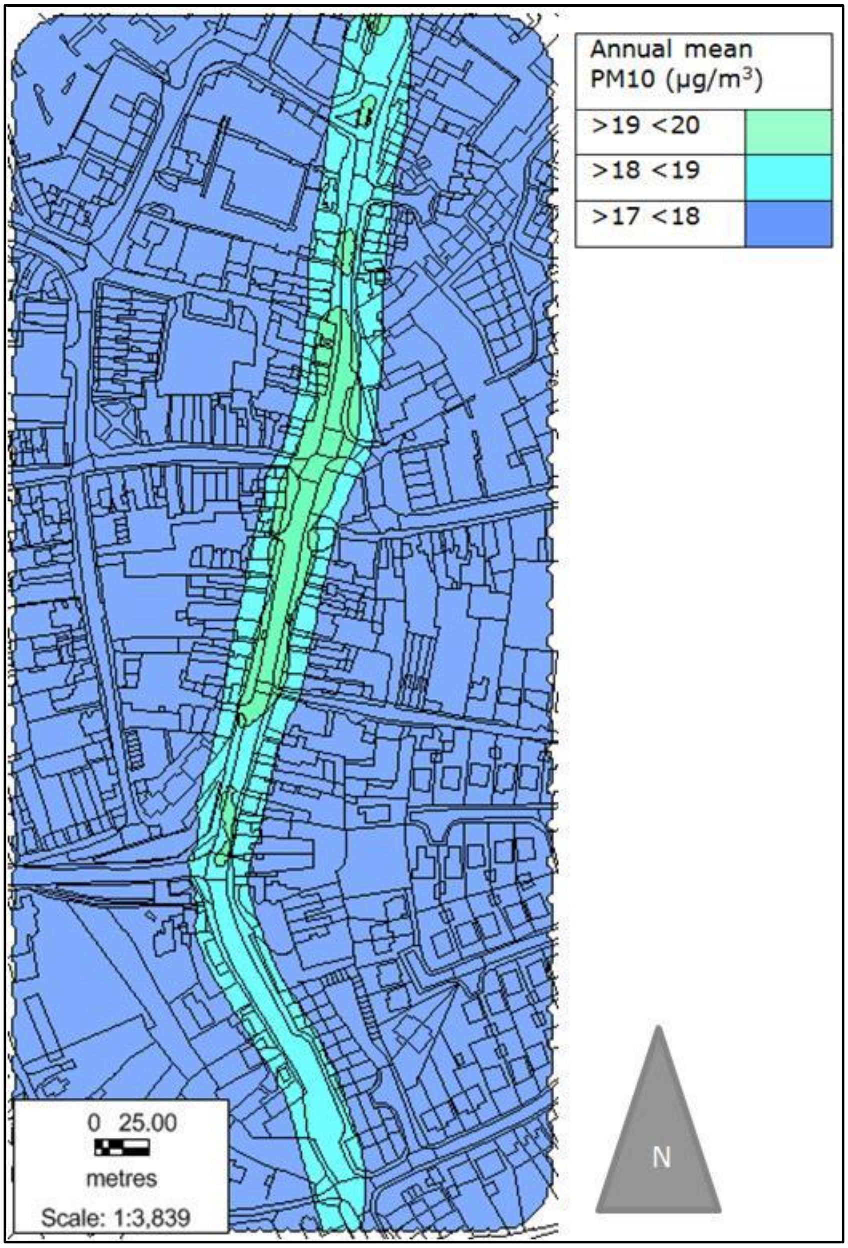


Figure 21. Annual mean $PM_{10}$ concentration contours with a 30 mph speed limit

# 4 Discussion and recommendations

This study involved detailed emissions analysis and modelling of a number of different data sources collected in Lutterworth. These included an ANPR camera survey that was conducted to determine the local vehicle fleet, a drive cycle survey that collected second by second on-board vehicle diagnostic parameters and instantaneous emissions modelling to determine second by second emissions from the drive cycle data. The overall aim of the study was to use these data sources to determine through modelling whether the introduction of a 20 mph zone on the High Street in Lutterworth could improve traffic related emissions of $NO_x$, PM and $CO_2$ pollutants and hence reduce $NO_2$ and $PM_{10}$ concentrations within the declared AQMA.

The survey found that there were more than 15,000 vehicles travelling along the road in a 24 hour period, and 30 percent of these were from through traffic. 94 percent of these vehicles were light duty (i.e. cars and vans) and the majority of these were diesel (63 percent). In terms of the contribution to emissions, light duty vehicles were responsible for around 45 percent of $NO_x$ emissions, 70 percent of $PM_{10}$ emissions and 75-80 percent of $CO_2$ emissions. Overall across all drive cycle runs, the average speed was below the existing 30 mph (48 km/h) speed limit with the maximum recorded speed being close to the speed limit.

The simulation of a 20 mph (32 km/h) speed limit as part of the drive cycle survey resulted in a reduction of average speed across all runs of around 4 km/h to 24.5 km/h (15 mph). In addition to this reduction in average speed, there was a reduction in the standard deviation of this speed from 12-13 km/h when driving in the 30 mph speed limit to 8 km/h when driving in the simulated 20 mph limit. This reduction in speed led to a positive effect by dampening acceleration events. As a result there was a reduction in average NOx, PM and $CO_2$ emissions across the northbound and southbound driving cycles of the order of 5 percent. The change in the number and severity of acceleration events in the drive cycle from a 30 mph to 20 mph provides the explanation for this overall reduction in emissions.

As this study analysed second by second data, it may be that there were acceleration peaks and subsequent higher emissions during the drive cycles that occurred at a higher resolution (i.e. 0.5 or 0.1 seconds) that have not been determined. It is possible therefore that the acceleration results and subsequent emission estimates may be on the conservative side. In addition, it is conceivable that a 20 mph speed limit would result in a reduction in traffic flow as vehicles divert to avoid the area. However, this was not tested in this study.

Based on the emissions assessment, dispersion modelling was conducted to determine the change in $NO_2$ and $PM_{10}$ concentrations due to the 20 mph speed limit. As part of the model verification process, a number of adjustments were made to the emission estimates in order to obtain a better agreement with the measured results. These included splitting the emission estimates into specific areas along the route, incorporating the impact of gradient and adjusting the emissions to better represent real driving $NO_x$ emissions. The results show that overall across all 371 modelled receptors that there was a reduction in modelled annual mean $NO_2$ concentrations by 3 percent (equal to 1.2 $\mu g/m^3$). There were some receptors where concentrations increased, these tended to be those close to the roadside on Market Street, where the road has a relatively steep gradient of 3.1 percent. The overall net reduction in the population weighted $NO_2$ concentration was 5 percent across the modelled area. Coloured contour maps were produced providing a visual representation of $NO_2$ and

$PM_{10}$ dispersion. For annual mean $NO_2$, the primary pollutant of concern, the maps clearly suggest that a speed limit reduction may spatially improve pollution along the High Street/Market Street areas. The maps also indicate that subject to location, benefits may be transferred up to 75m from the roadside.

The results of the emission modelling indicated that a 20 mph speed limit would have a reducing effect on road traffic $NO_X$ emissions. The absolute total emission results were further scrutinised with respect to ambient air quality monitoring data. A number of emissions modelling and air dispersion modelling adjustments were taken into account as part of this process. The level of detail applied to the study helps to improve confidence in the results. There were factors however which were not included in this study which may have had a material effect on the results. These include accounting for the level of traffic which could potentially be displaced elsewhere if a speed reduction was to be imposed.

On this basis, it is recommended that Harborough District Council considers the business case to impose a 20 mph speed limit. As well as including the cost benefits of improved air quality it may also like to consider other complementary environmental gains to offset capital costs.

## Glossary of terms and abbreviations

| | |
|---|---|
| AADT | Annual Average Daily Traffic |
| ADMS | Atmospheric Dispersion Modelling System |
| AQMA | Air Quality Management Area |
| ANPR | Automatic Number Plate Recognition (camera) |
| APA | Average Positive Acceleration |
| AQAP | Air Quality Action Plan |
| AQS | Air Quality Strategy |
| BAF | Bias Adjustment Factor |
| Defra | Department for Environment, Food and Rural Affairs |
| DfT | Department for Transport |
| DVLA | Driver Vehicle and Licensing Agency |
| EFT | Emission Factor Toolkit |
| HDC | Harborough District Council |
| HDV | Heavy Duty Vehicle (includes buses and HGVs) |
| HGV | Heavy Goods Vehicle (over 7.5 tonnes) |
| GIS | Geographic Information System |
| LAQM | Local Air Quality Management |
| LGV | Light Goods Vehicle (between 3.5 tonnes and 7.5 tonnes) |
| MAC | Marginal Abatement Costs |
| NAEI | National Atmospheric Emissions Inventory |
| NEDC | New European Drive Cycle |
| NO | Nitric Oxide |
| $NO_2$ | Nitrogen Dioxide |
| $NO_X$ | Total Oxides of Nitrogen |
| $O_3$ | Ozone |
| OS | Ordnance Survey |
| PHEM | Passenger car and Heavy duty Emission Model |
| $PM_{10}$ | Particulate matter less than 10 microns in diameter |
| RPA | Relative Positive Acceleration |
| TRL | Transport Research Laboratory |

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# Appendix A: Drive cycle statistics

Table 15: Drive cycle statistics for each cycle, 30 mph speed limit

| ID | Time start | Total time (min) | Average speed (km/h) | Max speed (km/h) | % Idle time | % Accel time | % Decel time | SD of speed (km/h) | APA (m/s$^2$) | RPA (m/$^2$) | Distance (km) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| NORTHBOUND DIRECTION | | | | | | | | | | | |
| 1_AM | 07:59:56 | 01:45 | 27.4 | 45.5 | 10% | 47% | 44% | 14.0 | 0.4 | 0.2 | 0.80 |
| 3_AM | 08:10:06 | 01:35 | 30.9 | 43.9 | 2% | 40% | 58% | 11.0 | 0.6 | 0.3 | 0.81 |
| 15_AM | 09:04:41 | 01:41 | 28.6 | 46.6 | 1% | 44% | 55% | 13.0 | 0.4 | 0.2 | 0.80 |
| 17_AM | 09:12:16 | 01:18 | 37.5 | 42.4 | 1% | 47% | 51% | 4.0 | 0.2 | 0.1 | 0.81 |
| 19_AM | 09:19:53 | 01:54 | 26.6 | 46.9 | 5% | 39% | 56% | 14.0 | 0.5 | 0.2 | 0.84 |
| 21_AM | 09:25:25 | 01:03 | 30.0 | 43.3 | 2% | 46% | 52% | 13.0 | 0.4 | 0.2 | 0.53 |
| 23_AM | 09:32:26 | 01:40 | 28.6 | 45.3 | 10% | 36% | 54% | 14.0 | 0.4 | 0.1 | 0.79 |
| 1_IP | 12:08:24 | 02:01 | 23.4 | 43.5 | 14% | 35% | 51% | 15.2 | 0.5 | 0.2 | 0.79 |
| 3_IP | 12:18:04 | 03:13 | 14.6 | 47.0 | 2% | 52% | 46% | 11.6 | 0.3 | 0.2 | 0.78 |
| 5_IP | 12:25:59 | 01:17 | 37.4 | 54.4 | 3% | 48% | 49% | 5.5 | 0.2 | 0.1 | 0.80 |
| 7_IP | 12:35:37 | 01:46 | 27.0 | 45.5 | 5% | 48% | 47% | 15.5 | 0.3 | 0.2 | 0.79 |
| 9_IP | 12:43:34 | 01:31 | 31.3 | 44.4 | 3% | 46% | 51% | 12.6 | 0.5 | 0.2 | 0.79 |
| 1_PM | 17:01:04 | 01:17 | 37.2 | 48.7 | 1% | 40% | 58% | 5.5 | 0.3 | 0.1 | 0.80 |
| 3_PM | 17:08:39 | 01:47 | 26.8 | 47.7 | 1% | 47% | 52% | 14.0 | 0.4 | 0.2 | 0.80 |
| 5_PM | 17:22:42 | 01:48 | 27.0 | 46.8 | 2% | 43% | 56% | 13.2 | 0.4 | 0.2 | 0.81 |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 7_PM | 17:38:27 | 01:47 | 27.4 | 41.7 | 4% | 50% | 47% | 10.5 | 0.4 | 0.2 | 0.81 |
| 9_PM | 17:54:59 | 01:49 | 26.0 | 43.1 | 3% | 45% | 52% | 13.2 | 0.4 | 0.2 | 0.79 |
| 21_PM | 18:58:05 | 01:47 | 26.7 | 45.0 | 11% | 41% | 48% | 15.8 | 0.7 | 0.2 | 0.79 |
| 23_PM | 19:05:32 | 01:17 | 36.9 | 45.1 | 3% | 45% | 52% | 6.2 | 0.3 | 0.1 | 0.79 |
| SOUTHBOUND DIRECTION | | | | | | | | | | | |
| 14_AM | 09:01:15 | 01:28 | 32.0 | 44.1 | 2% | 50% | 48% | 16.4 | 0.6 | 0.2 | 0.78 |
| 16_AM | 09:09:04 | 01:55 | 24.6 | 44.4 | 2% | 58% | 40% | 11.5 | 0.4 | 0.2 | 0.79 |
| 18_AM | 09:15:38 | 01:47 | 26.8 | 46.5 | 11% | 52% | 36% | 12.6 | 0.5 | 0.2 | 0.80 |
| 20_AM | 09:22:25 | 01:18 | 35.5 | 45.0 | 3% | 54% | 44% | 6.3 | 0.3 | 0.2 | 0.77 |
| 22_AM | 09:28:44 | 01:28 | 31.8 | 46.6 | 5% | 51% | 44% | 16.1 | 0.6 | 0.3 | 0.78 |
| 2_IP | 12:11:53 | 01:34 | 29.8 | 44.2 | 2% | 54% | 44% | 11.5 | 0.4 | 0.2 | 0.78 |
| 4_IP | 12:22:20 | 02:22 | 19.4 | 43.7 | 11% | 52% | 37% | 13.4 | 0.5 | 0.3 | 0.77 |
| 6_IP | 12:31:09 | 03:03 | 15.0 | 39.5 | 23% | 39% | 37% | 13.1 | 0.5 | 0.2 | 0.76 |
| 8_IP | 12:40:09 | 01:47 | 25.7 | 45.9 | 8% | 50% | 41% | 14.3 | 0.4 | 0.2 | 0.76 |
| 10_IP | 12:48:32 | 01:40 | 28.0 | 45.3 | 3% | 53% | 44% | 13.5 | 0.5 | 0.3 | 0.78 |
| 2_PM | 17:03:53 | 01:16 | 36.6 | 44.5 | 3% | 46% | 51% | 8.7 | 0.6 | 0.3 | 0.77 |
| 22_PM | 19:01:14 | 01:32 | 30.3 | 44.1 | 5% | 47% | 48% | 13.9 | 0.7 | 0.4 | 0.77 |
| 24_PM | 19:08:41 | 01:25 | 32.6 | 44.6 | 4% | 55% | 41% | 11.6 | 0.4 | 0.2 | 0.77 |

Table 16: Drive cycle statistics for each cycle, 20 mph speed limit

| ID | Time start | Total time (min) | Average speed (km/h) | Max speed (km/h) | % Idle time | % Accel time | % Decel time | SD of speed (km/h) | APA ($m/s^2$) | RPA ($m/s^2$) | Distance (km) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| NORTHBOUND DIRECTION | | | | | | | | | | | |
| 5_AM | 08:17:33 | 01:54 | 26.7 | 42.8 | 6% | 48% | 46% | 10.2 | 0.3 | 0.1 | 0.84 |
| 7_AM | 08:26:35 | 01:57 | 23.7 | 42.0 | 1% | 50% | 49% | 11.2 | 0.4 | 0.2 | 0.77 |
| 9_AM | 08:39:35 | 03:06 | 15.6 | 33.7 | 17% | 41% | 41% | 10.1 | 0.4 | 0.2 | 0.81 |
| 11_AM | 08:49:13 | 01:46 | 26.0 | 38.4 | 1% | 43% | 56% | 12.2 | 0.4 | 0.2 | 0.77 |
| 13_AM | 08:57:46 | 01:42 | 28.3 | 37.9 | 1% | 47% | 52% | 4.6 | 0.2 | 0.1 | 0.80 |
| 11_IP | 12:52:40 | 02:05 | 23.4 | 44.3 | 11% | 37% | 52% | 11.0 | 0.4 | 0.1 | 0.81 |
| 13_IP | 13:02:16 | 03:07 | 15.3 | 42.2 | 10% | 42% | 48% | 10.4 | 0.4 | 0.2 | 0.80 |
| 15_IP | 13:10:26 | 01:39 | 28.8 | 50.1 | 1% | 44% | 55% | 5.8 | 0.3 | 0.1 | 0.79 |
| 17_IP | 13:19:09 | 01:57 | 24.7 | 44.0 | 12% | 44% | 44% | 12.2 | 0.3 | 0.1 | 0.80 |
| 19_IP | 13:27:52 | 01:56 | 24.9 | 38.2 | 7% | 42% | 51% | 9.9 | 0.3 | 0.1 | 0.80 |
| 11_PM | 18:09:03 | 01:35 | 30.3 | 36.2 | 1% | 44% | 55% | 2.4 | 0.2 | 0.1 | 0.80 |
| 13_PM | 18:22:53 | 01:34 | 29.8 | 42.8 | 1% | 51% | 48% | 3.1 | 0.2 | 0.1 | 0.78 |
| 15_PM | 18:34:03 | 01:34 | 30.5 | 44.8 | 2% | 43% | 55% | 4.0 | 0.2 | 0.1 | 0.80 |
| 17_PM | 18:42:01 | 02:16 | 21.1 | 42.6 | 22% | 32% | 46% | 12.7 | 0.4 | 0.1 | 0.80 |
| 19_PM | 18:49:28 | 01:47 | 26.6 | 39.9 | 4% | 42% | 54% | 8.9 | 0.4 | 0.2 | 0.79 |
| 25_PM | 19:12:19 | 01:32 | 30.3 | 47.2 | 1% | 51% | 48% | 3.5 | 0.3 | 0.1 | 0.78 |

| SOUTHBOUND DIRECTION | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 2_AM | 08:05:15 | 02:02 | 23.3 | 34.5 | 5% | 51% | 44% | 8.6 | 0.5 | 0.2 | 0.79 |
| 4_AM | 08:13:27 | 01:37 | 29.2 | 39.4 | 1% | 53% | 46% | 5.8 | 0.4 | 0.2 | 0.79 |
| 6_AM | 08:21:28 | 01:52 | 25.4 | 33.3 | 1% | 60% | 39% | 7.3 | 0.3 | 0.2 | 0.79 |
| 8_AM | 08:34:13 | 02:26 | 19.1 | 31.0 | 1% | 57% | 42% | 7.8 | 0.4 | 0.2 | 0.78 |
| 10_AM | 08:44:39 | 02:33 | 18.3 | 31.4 | 12% | 51% | 37% | 9.8 | 0.3 | 0.2 | 0.78 |
| 12_AM | 08:53:18 | 02:03 | 22.6 | 32.0 | 2% | 61% | 37% | 8.8 | 0.3 | 0.1 | 0.77 |
| 12_IP | 12:57:12 | 02:26 | 19.0 | 35.1 | 1% | 55% | 44% | 9.8 | 0.6 | 0.3 | 0.77 |
| 14_IP | 13:06:36 | 01:57 | 23.8 | 33.8 | 13% | 46% | 41% | 10.3 | 0.3 | 0.2 | 0.77 |
| 16_IP | 13:15:02 | 02:27 | 18.7 | 32.2 | 1% | 50% | 49% | 8.7 | 0.3 | 0.2 | 0.76 |
| 18_IP | 13:23:10 | 01:52 | 24.7 | 42.2 | 2% | 59% | 39% | 10.6 | 0.4 | 0.2 | 0.77 |
| 20_IP | 13:32:53 | 02:50 | 16.1 | 32.0 | 26% | 39% | 34% | 12.6 | 0.3 | 0.1 | 0.76 |
| 16_PM | 18:37:23 | 01:37 | 28.6 | 34.1 | 2% | 51% | 47% | 1.8 | 0.2 | 0.1 | 0.77 |
| 18_PM | 18:45:28 | 01:34 | 29.7 | 33.9 | 2% | 49% | 49% | 2.1 | 0.2 | 0.1 | 0.77 |
| 20_PM | 18:53:00 | 01:38 | 28.6 | 33.8 | 1% | 51% | 48% | 3.0 | 0.2 | 0.1 | 0.78 |
| 26_PM | 19:16:13 | 01:50 | 25.6 | 36.1 | 3% | 48% | 49% | 9.3 | 0.4 | 0.2 | 0.78 |

Table 17: Drive cycle statistics for each cycle, congested situation

| ID | Time start | Total time (min) | Average speed (km/h) | Max speed (km/h) | % Idle time | % Accel time | % Decel time | SD of speed (km/h) | APA ($m/s^2$) | RPA ($m/^2$) | Distance (km) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| SOUTHBOUND DIRECTION | | | | | | | | | | | |
| 4_PM | 17:17:10 | 06:08 | 7.5 | 33.9 | 26% | 37% | 38% | 8.3 | 0.5 | 0.3 | 0.76 |
| 6_PM | 17:33:50 | 09:01 | 5.1 | 26.2 | 29% | 32% | 39% | 5.7 | 0.4 | 0.2 | 0.76 |
| 8_PM | 17:48:42 | 06:43 | 6.9 | 25.5 | 22% | 37% | 42% | 5.9 | 0.4 | 0.2 | 0.77 |
| 10_PM | 18:04:52 | 06:59 | 6.6 | 34.0 | 38% | 30% | 32% | 8.1 | 0.4 | 0.2 | 0.77 |
| 12_PM | 18:18:25 | 06:38 | 6.9 | 23.6 | 23% | 38% | 39% | 5.7 | 0.3 | 0.2 | 0.76 |
| 14_PM | 18:29:26 | 04:28 | 10.3 | 30.1 | 13% | 45% | 41% | 7.6 | 0.4 | 0.2 | 0.77 |

# Appendix B: Drive cycle emissions

Table 18: Emission statistics for each cycle, 30 mph speed limit

| ID | NOx emissions | | | | PM emissions | | | | CO2 emissions | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | LDV g | HDV g | LDV g/km | HDV g/km | LDV g | HDV g | LDV g/km | HDV g/km | LDV g | HDV g | LDV g/km | HDV g/km |
| NORTHBOUND DIRECTION | | | | | | | | | | | | |
| 1_AM | 0.18 | 3.73 | 0.23 | 4.67 | 0.01 | 0.07 | 0.01 | 0.08 | 135.3 | 691.2 | 169.34 | 864.96 |
| 3_AM | 0.20 | 3.67 | 0.24 | 4.50 | 0.01 | 0.06 | 0.01 | 0.08 | 131.8 | 737.7 | 161.78 | 905.33 |
| 15_AM | 0.19 | 3.43 | 0.24 | 4.27 | 0.01 | 0.06 | 0.01 | 0.08 | 130.6 | 680.9 | 162.46 | 847.36 |
| 17_AM | 0.15 | 3.23 | 0.18 | 3.98 | 0.01 | 0.05 | 0.01 | 0.07 | 114.5 | 462.7 | 141.09 | 570.25 |
| 19_AM | 0.22 | 4.18 | 0.26 | 4.96 | 0.01 | 0.08 | 0.01 | 0.09 | 155.7 | 835.2 | 185.01 | 992.27 |
| 21_AM | 0.12 | 2.36 | 0.23 | 4.50 | 0.01 | 0.04 | 0.01 | 0.08 | 88.0 | 429.3 | 167.37 | 816.80 |
| 23_AM | 0.17 | 3.57 | 0.22 | 4.49 | 0.01 | 0.06 | 0.01 | 0.08 | 125.7 | 615.1 | 158.17 | 773.74 |
| 1_IP | 0.21 | 4.08 | 0.26 | 5.20 | 0.01 | 0.07 | 0.01 | 0.09 | 146.0 | 779.2 | 185.84 | 991.87 |
| 3_IP | 0.28 | 4.97 | 0.35 | 6.34 | 0.01 | 0.11 | 0.02 | 0.14 | 198.9 | 982.4 | 253.80 | 1253.65 |
| 5_IP | 0.15 | 3.49 | 0.18 | 4.36 | 0.01 | 0.06 | 0.01 | 0.08 | 110.8 | 513.8 | 138.44 | 642.13 |
| 7_IP | 0.20 | 3.96 | 0.25 | 4.99 | 0.01 | 0.07 | 0.01 | 0.09 | 145.0 | 703.8 | 182.57 | 886.31 |
| 9_IP | 0.19 | 3.78 | 0.24 | 4.78 | 0.01 | 0.06 | 0.01 | 0.08 | 133.0 | 718.1 | 168.01 | 907.10 |
| 1_PM | 0.15 | 3.22 | 0.18 | 4.04 | 0.01 | 0.06 | 0.01 | 0.07 | 113.8 | 480.3 | 142.93 | 603.12 |
| 3_PM | 0.19 | 3.72 | 0.24 | 4.66 | 0.01 | 0.07 | 0.01 | 0.09 | 139.5 | 656.2 | 174.98 | 822.95 |
| 5_PM | 0.19 | 3.75 | 0.23 | 4.63 | 0.01 | 0.07 | 0.01 | 0.09 | 138.1 | 695.3 | 170.50 | 858.41 |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 7_PM | 0.20 | 4.11 | 0.25 | 5.05 | 0.01 | 0.07 | 0.01 | 0.09 | 148.1 | 796.7 | 182.21 | 980.02 |
| 9_PM | 0.20 | 3.87 | 0.25 | 4.91 | 0.01 | 0.07 | 0.01 | 0.09 | 138.8 | 726.4 | 176.43 | 923.28 |
| 21_PM | 0.23 | 4.39 | 0.29 | 5.54 | 0.01 | 0.07 | 0.01 | 0.09 | 152.1 | 834.8 | 191.94 | 1053.75 |
| 23_PM | 0.15 | 3.43 | 0.20 | 4.35 | 0.01 | 0.06 | 0.01 | 0.07 | 117.3 | 522.5 | 148.75 | 662.51 |
| 14_AM | 0.21 | 4.23 | 0.26 | 5.41 | 789.3 | 0.022 | 0.01 | 0.09 | 144.6 | 789.3 | 185.18 | 1010.53 |
| 16_AM | 0.22 | 4.49 | 0.28 | 5.70 | 793.3 | 0.023 | 0.02 | 0.11 | 161.2 | 793.3 | 204.79 | 1007.77 |
| 18_AM | 0.24 | 4.98 | 0.30 | 6.26 | 888.8 | 0.025 | 0.02 | 0.10 | 161.1 | 888.8 | 202.42 | 1117.07 |
| 20_AM | 0.19 | 4.20 | 0.25 | 5.46 | 730.1 | 0.021 | 0.01 | 0.09 | 133.1 | 730.1 | 173.08 | 949.37 |
| 22_AM | 0.23 | 4.47 | 0.30 | 5.76 | 886.5 | 0.024 | 0.01 | 0.09 | 151.3 | 886.5 | 194.75 | 1141.17 |
| SOUTHBOUND DIRECTION | | | | | | | | | | | | |
| 2_IP | 0.21 | 4.40 | 0.27 | 5.64 | 808.6 | 0.022 | 0.01 | 0.10 | 147.1 | 808.6 | 188.85 | 1037.81 |
| 4_IP | 0.29 | 5.33 | 0.37 | 6.95 | 1146.7 | 0.031 | 0.02 | 0.13 | 197.2 | 1146.7 | 257.11 | 1495.31 |
| 6_IP | 0.27 | 5.42 | 0.35 | 7.09 | 999.0 | 0.029 | 0.02 | 0.14 | 201.0 | 999.0 | 263.22 | 1308.31 |
| 8_IP | 0.22 | 4.66 | 0.29 | 6.10 | 876.8 | 0.024 | 0.01 | 0.11 | 152.1 | 876.8 | 199.25 | 1148.42 |
| 10_IP | 0.27 | 4.85 | 0.35 | 6.24 | 1017.8 | 0.029 | 0.02 | 0.11 | 166.0 | 1017.8 | 213.43 | 1309.05 |
| 2_PM | 0.19 | 4.01 | 0.25 | 5.19 | 708.1 | 0.021 | 0.01 | 0.08 | 131.2 | 708.1 | 169.66 | 915.97 |
| 22_PM | 0.22 | 4.26 | 0.28 | 5.50 | 829.4 | 0.023 | 0.02 | 0.09 | 150.6 | 829.4 | 194.43 | 1070.70 |
| 24_PM | 0.21 | 4.46 | 0.28 | 5.80 | 822.0 | 0.023 | 0.02 | 0.09 | 150.2 | 822.0 | 195.14 | 1068.23 |

Table 19: Emissions statistics for each cycle, 20 mph speed limit

| ID | NOx emissions | | | | PM emissions | | | | CO2 emissions | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | LDV g | HDV g | LDV g/km | HDV g/km | LDV g | HDV g | LDV g/km | HDV g/km | LDV g | HDV g | LDV g/km | HDV g/km |
| NORTHBOUND DIRECTION | | | | | | | | | | | | |
| 5_AM | 0.19 | 3.96 | 0.23 | 4.69 | 658.3 | 0.020 | 0.01 | 0.08 | 144.0 | 658.3 | 170.66 | 779.96 |
| 7_AM | 0.20 | 3.79 | 0.26 | 4.92 | 689.0 | 0.022 | 0.01 | 0.10 | 148.1 | 689.0 | 192.19 | 894.34 |
| 9_AM | 0.25 | 4.68 | 0.31 | 5.80 | 881.0 | 0.027 | 0.01 | 0.12 | 183.1 | 881.0 | 227.20 | 1092.97 |
| 11_AM | 0.16 | 3.26 | 0.21 | 4.25 | 540.2 | 0.018 | 0.01 | 0.07 | 121.5 | 540.2 | 158.54 | 704.64 |
| 13_AM | 0.16 | 3.44 | 0.20 | 4.29 | 489.4 | 0.017 | 0.01 | 0.07 | 118.6 | 489.4 | 147.97 | 610.48 |
| 11_IP | 0.19 | 3.48 | 0.23 | 4.29 | 638.6 | 0.020 | 0.01 | 0.08 | 135.3 | 638.6 | 166.64 | 786.22 |
| 13_IP | 0.26 | 4.67 | 0.33 | 5.88 | 958.9 | 0.028 | 0.01 | 0.12 | 186.7 | 958.9 | 234.67 | 1205.44 |
| 15_IP | 0.15 | 3.28 | 0.19 | 4.14 | 492.1 | 0.017 | 0.01 | 0.07 | 112.9 | 492.1 | 142.40 | 620.43 |
| 17_IP | 0.18 | 3.88 | 0.22 | 4.84 | 587.0 | 0.019 | 0.01 | 0.08 | 133.3 | 587.0 | 166.29 | 732.31 |
| 19_IP | 0.18 | 3.64 | 0.22 | 4.53 | 600.2 | 0.019 | 0.01 | 0.08 | 133.9 | 600.2 | 166.81 | 747.72 |
| 11_PM | 0.15 | 3.31 | 0.18 | 4.15 | 441.8 | 0.016 | 0.01 | 0.07 | 117.4 | 441.8 | 146.96 | 552.84 |
| 13_PM | 0.15 | 3.22 | 0.19 | 4.14 | 446.8 | 0.016 | 0.01 | 0.07 | 114.0 | 446.8 | 146.46 | 574.01 |
| 15_PM | 0.14 | 3.19 | 0.17 | 4.00 | 454.9 | 0.015 | 0.01 | 0.07 | 111.6 | 454.9 | 139.94 | 570.52 |
| 17_PM | 0.19 | 3.82 | 0.24 | 4.80 | 657.1 | 0.021 | 0.01 | 0.09 | 142.2 | 657.1 | 178.61 | 825.49 |
| 19_PM | 0.19 | 3.92 | 0.24 | 4.95 | 649.3 | 0.021 | 0.01 | 0.09 | 134.7 | 649.3 | 170.07 | 819.88 |
| 25_PM | 0.14 | 3.25 | 0.18 | 4.19 | 424.6 | 0.016 | 0.01 | 0.07 | 107.4 | 424.6 | 138.54 | 547.67 |

| SOUTHBOUND DIRECTION | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2_AM | 0.22 | 4.56 | 0.28 | 5.78 | 801.1 | 0.023 | 0.01 | 0.10 | 153.6 | 801.1 | 194.69 | 1015.30 |
| 4_AM | 0.19 | 4.18 | 0.24 | 5.32 | 657.1 | 0.020 | 0.01 | 0.09 | 140.3 | 657.1 | 178.50 | 835.77 |
| 6_AM | 0.19 | 4.24 | 0.24 | 5.38 | 646.3 | 0.020 | 0.01 | 0.09 | 141.0 | 646.3 | 178.76 | 819.14 |
| 8_AM | 0.24 | 4.62 | 0.31 | 5.96 | 845.0 | 0.025 | 0.02 | 0.12 | 175.6 | 845.0 | 226.53 | 1089.91 |
| 10_AM | 0.24 | 4.37 | 0.31 | 5.62 | 885.4 | 0.026 | 0.01 | 0.11 | 172.9 | 885.4 | 222.64 | 1140.40 |
| 12_AM | 0.20 | 4.19 | 0.26 | 5.43 | 726.4 | 0.022 | 0.01 | 0.10 | 152.1 | 726.4 | 196.96 | 940.73 |
| 12_IP | 0.32 | 5.68 | 0.41 | 7.36 | 1192.6 | 0.034 | 0.02 | 0.15 | 209.6 | 1192.6 | 271.88 | 1547.07 |
| 14_IP | 0.20 | 4.60 | 0.26 | 5.95 | 749.6 | 0.022 | 0.01 | 0.10 | 149.1 | 749.6 | 192.81 | 969.48 |
| 16_IP | 0.22 | 4.45 | 0.29 | 5.84 | 764.3 | 0.024 | 0.01 | 0.12 | 160.1 | 764.3 | 210.01 | 1002.71 |
| 18_IP | 0.22 | 4.51 | 0.28 | 5.86 | 802.4 | 0.023 | 0.01 | 0.10 | 155.9 | 802.4 | 202.62 | 1042.75 |
| 20_IP | 0.21 | 4.49 | 0.28 | 5.92 | 697.6 | 0.023 | 0.01 | 0.11 | 164.8 | 697.6 | 217.24 | 919.72 |
| 16_PM | 0.18 | 3.67 | 0.23 | 4.75 | 559.8 | 0.019 | 0.01 | 0.08 | 123.1 | 559.8 | 159.43 | 725.25 |
| 18_PM | 0.16 | 3.73 | 0.21 | 4.81 | 545.2 | 0.017 | 0.01 | 0.08 | 121.3 | 545.2 | 156.58 | 703.51 |
| 20_PM | 0.17 | 4.02 | 0.22 | 5.17 | 598.2 | 0.018 | 0.01 | 0.08 | 127.0 | 598.2 | 163.36 | 769.43 |
| 26_PM | 0.21 | 4.25 | 0.27 | 5.44 | 735.4 | 0.022 | 0.01 | 0.09 | 146.6 | 735.4 | 187.51 | 940.57 |

Table 20: Emissions statistics for each cycle, congested situation

| ID | NOx emissions | | | | PM emissions | | | | CO2 emissions | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | LDV g | HDV g | LDV g/km | HDV g/km | LDV g | HDV g | LDV g/km | HDV g/km | LDV g | HDV g | LDV g/km | HDV g/km |
| 4_PM | 0.431 | 8.059 | 0.57 | 10.56 | 1583.1 | 0.047 | 0.02 | 0.23 | 310.2 | 1583.1 | 406.54 | 2075.10 |
| 6_PM | 0.460 | 8.769 | 0.61 | 11.53 | 1441.0 | 0.050 | 0.02 | 0.26 | 362.4 | 1441.0 | 476.56 | 1895.10 |
| 8_PM | 0.383 | 7.081 | 0.50 | 9.21 | 1260.8 | 0.041 | 0.02 | 0.22 | 293.9 | 1260.8 | 382.38 | 1640.15 |
| 10_PM | 0.384 | 7.465 | 0.50 | 9.75 | 1241.1 | 0.041 | 0.02 | 0.22 | 298.9 | 1241.1 | 390.27 | 1620.21 |
| 12_PM | 0.379 | 7.194 | 0.50 | 9.43 | 1231.9 | 0.041 | 0.02 | 0.21 | 294.0 | 1231.9 | 385.42 | 1615.02 |
| 14_PM | 0.322 | 5.831 | 0.42 | 7.58 | 1144.8 | 0.035 | 0.02 | 0.17 | 244.6 | 1144.8 | 318.10 | 1488.72 |

# Emissions and air quality assessment of a 20 mph speed limit in the Lutterworth AQMA

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