1. Introduction

Context
The focus of this study has been to investigate the reasons for the poor air quality in and around the A38 near Derby and provide an indication whether anything can be done to improve specific air quality issues relating to the A38 in this area. Annual mean concentrations of nitrogen dioxide (NO₂) exceed the Air Quality Strategy (AQS) objective at a number of locations this area, therefore this pollutant has been the focus of this investigation as it is of principal concern.

This study has taken a forensic approach to analysing the available information, building a comprehensive picture of the air quality and traffic conditions in this area, to better understand the root causes for elevated NO₂ concentrations.

Study Area
The A38 is a major (non-motorway) north-south route that is included as part of the UK Government’s Strategic Road Network between Birmingham and the Nottingham-Derby area. At its northern and southern extents, the road connects the M1 and M6 motorways. Where the A38 passes through the western and northern parts of Derby, local intra-urban trips cross the A38 on roads into the city or use the A38 to travel around Derby. The interaction between strategic and local trips results in delays at the three roundabout junctions on the A38, namely the A38/A5111 Kingsway junction, the A38/A52 Markeaton junction and the A38/A61 Little Eaton junction to the west of Derby City centre. The study area considered is shown in Figure 1.

![Study Area, Highlighting Key Urban Areas and Roads Close to the A38 Derby](image)

Derby and its immediate surrounding area are expected to accommodate significant housing and employment growth in the coming years. This is expected to increase traffic flows on the A38 through Derby, which are expected to grow more quickly than the national average. The proposed Highways England Derby Junctions scheme aims to accommodate future traffic growth, with local junction and mainline improvements increasing capacity. The scheme also aims to reduce congestion through specific Junction improvements.
Derby is also one of the five cities outside of London mandated to implement a Clean Air Zone (CAZ) in their city by 2020. Derby’s commitment to implement a CAZ is likely to impact on the diesel portion of the vehicle fleet inside the Derby Inner ring road area and on the surrounding road network.

Traffic Conditions

Traffic data for this study have been collected and analysed from several sources, including Trafficmaster speed data (GPS sourced), traffic count datasets from Highways England and the Department for Transport and a traffic model developed for the Highways England Derby Juncions scheme. In addition, to understand the types of vehicle making use of the different roads within the study area, an Automatic Number Plate Recognition (ANPR) survey was undertaken at the ten locations shown in Figure 2. The survey captured the number plates of vehicles as they drove past, allowing the type and age of the vehicle to be determined from a large database.

Air Quality Conditions

Air quality measurement data within the study area were considered. The only available data were from diffusion tubes; small, plastic tubes which contain a chemical reagent to absorb NO₂ from the air. These devices, whilst being less accurate than continuous monitoring stations (CMS), are small and can be affixed easily to lampposts or property facades in areas of concern. Other data sources have also been considered, including databases of industrial emissions held by Defra and the Environment Agency, information on terrain and meteorology, and detailed maps and photographs of the area.

The availability of air quality monitoring data was a limiting factor to this study, given the absence of CMS within the study area that provide more accurate, high resolution hourly data. Results from diffusion tube monitoring undertaken by both Derby City Council and Highways England were, however, available and used to understand annual mean NO₂ concentrations spatially and by source contribution.

As illustrated in Figure 3, these monitoring data indicate that annual mean NO₂ concentrations exceeded the level of the AQS objective (40 µg/m³) at 3 out of 20 sites alongside the A38 in 2015 (the latest full calendar year for which data were available). All three of these sites are located close to the A38, but at a distance greater than 10m from the nearest sensitive receptor (e.g. school, hospital or residential property) where the AQS objective is relevant.

The monitoring undertaken in the same year adjacent to the adjoining arterial roads into Derby indicate that the level of the AQS objective was exceeded at 19 out of 100 sites. In contrast to those sites adjacent to the A38 however, whilst similar or higher NO₂ concentrations were measured, these sites are positioned closer to the nearest locations of relevant exposure. This indicates that annual mean NO₂ concentrations are of greater concern at locations within Derby than alongside the A38.
Study Objectives

It is considered that the A38 Derby could influence annual mean NO₂ concentrations in the study area as a result of:

1) Direct emissions relating to the volume and composition of road traffic on the A38;
2) Direct emissions due to congestion around the junctions of the A38 with its arterial roads; and
3) Emissions associated with traffic on arterial roads caused by vehicles accessing the A38.

The study objectives were therefore aimed at investigating each of these influences and how they relate to measured NO₂ concentrations in the study area.
2. Background Contribution

The background contribution is the contribution to measured concentrations from emission sources some distance away from the point of measurement. Background concentrations can be further divided into ‘regional’ and ‘local’ components. A regional background can be monitored in isolated rural areas and originates from emission sources across the UK and Europe. As no rural monitoring sites were available within the vicinity of the study area, urban background monitoring data for 2015 were used to understand total background NO$_2$ concentrations across the study area. These data indicate that background NO$_2$ concentrations ranged between 16 and 20 µg/m$^3$ across the study area.

Local background concentrations are made up from emissions from many different sources, which can be approximately characterised as shown in Figure 4. Road traffic emissions contribute 4.3 µg/m$^3$ of the local background around the A38 Derby, with this being the combined influence of the A38, its adjoining arterial roads and minor roads over the wider area. Approximately 1 µg/m$^3$ of the local background is attributable to industrial, commercial, institutional and domestic sources. Given the relatively small contributions from local background sources, a large component of the total background concentration is the regional (rural) contribution.

Figure 4: Indicative Breakdown of NO$_2$ (µg/m$^3$) from Local Background Sources on A38 Kingsway in 2015

3. Meteorology

The meteorological conditions in this area show the strongest and most frequent winds originate from the southwest and west. This will mean that, for most of the time, air pollution will be carried north eastward and eastward from emissions sources. It is, however, important to note that high pollution concentrations can occur in all wind directions, particularly when wind speeds are lower, as then pollutants in the air are less well dispersed, so their concentrations can build up.

Figure 5: 2014 - 2016 East Midland Airport Windroses showing wind direction and speed
4. Road Traffic Conditions

The origins and destinations of road traffic movements, congestion and vehicle fleet composition all have the potential to influence road traffic emissions. Traffic data for both the A38 and its arterial roads were therefore explored to obtain a better understanding of how such factors might influence road traffic emissions and local air quality adjacent to roads in the study area.

Origin & Destination Data

The A38 Derby Junctions traffic model was analysed to understand vehicle movements across the study area and their associated origins and destinations. The purpose of this analysis was to determine whether the air quality issues on the A38 and in the Derby area are a result of long distance traffic, local traffic or a combination of the two. The analysis suggests that there is little mixing between traffic on the A38 and its arterial roads at the A52, A5111 and A516 Junctions. Consequently, reducing emissions from vehicles using the A38 main carriageway would do very little to reduce concentrations on its arterial roads, where NO\textsubscript{2} concentrations exceed AQS objectives. There is, however, a significant volume of traffic that uses the A38 south of Derby to access the A516 Uttoxeter New Road, which contributes to some exceedances of the NO\textsubscript{2} AQS objective along this road. This route adjoins the A38 Kingsway which is one of the junctions that is being improved as part of the Highways England scheme.

Congestion

Based on observed speeds, the northbound A38 in Derby is predominantly free flowing, with lower speeds observed at the approaches to the A38/A5111 Kingsway and A38/A52 Markeaton Junction. Observed speeds for the A38 southbound are lower than in the northbound direction, but are also largely free flowing, except at the approach to the A38/A52 Markeaton Junction on the A38 Queensway, where lower average speeds are indicative of queuing and stop-start traffic.

Queuing traffic leading up to the A38 Derby Junctions both on the A38 and its adjoining arterial roads is evident during peak traffic periods, which has the potential to result in elevated emissions and higher NO\textsubscript{2} concentrations at nearby receptors. It is thought likely that congestion leading up to the A38 Junctions is a major contributor to the air quality problems along Derby's arterial roads.

Vehicle Fleet Composition

ANPR data were used to understand differences in fleet make up across the study area and compared to national projections. Heavy Goods Vehicle (HGV) proportions were between 8 and 10% of the total fleet along all surveyed sections of the A38, compared to 1 – 3% on the adjoining arterial roads in Derby. The petrol car proportions on the A38 were also lower than national projections and along adjoining arterial roads. These differences suggest the A38 is a more strategic route (with a fleet makeup more similar to a motorway) as HGVs typically travel longer distances and petrol cars shorter distances.

The vehicle fleet in Derby is also generally older, and therefore likely to have higher emissions, than suggested by national estimates used for emission projections, both along the A38 and its adjoining arterial roads, with a lot more Euro 4 / IV and Euro 5 / V vehicles and a lot less more modern Euro 6 / VI vehicles, for all vehicle types.

5. Source Apportionment

Analysis of Measured NO\textsubscript{2} Concentrations

The analysis of measurements made close to roads across the study area has shown that variations in measured concentrations can largely be explained by the background contribution, the distance of the monitor from the nearest major road and variations in traffic volume and composition. However, measured
concentrations at certain locations are influenced by other local factors. The key factors which influence the elevated NO₂ concentrations measured adjacent to the A52, A516 and A5111 are found to be a combination of the close proximity of the monitors to the A38 and its junctions leading into Derby, and the congestion associated with these sections of road.

The line shown in Figure 7 has been inferred from the measurements made alongside the A38 near Derby. It shows that the A38 has a very large effect on concentrations very close to the road, but this drops off rapidly with distance from the road resulting in a relatively modest effect on NOₓ concentrations.

Figure 6: Road NOₓ with distance from the A38

**Contribution by Vehicle Type**

Indicative calculations suggest that the contribution from road traffic to annual mean NO₂ concentrations in and around the A38 in Derby is dominated by the contributions made by diesel cars and LGVs, as shown for the A38 in Figure 6.

It was found that for all vehicle types, vehicles meeting the Euro 4 / IV and Euro 5 / V emission standards are the largest contributors to NO₂ concentrations in Derby. The vehicle fleet in Derby is older than the national average, as defined by the dataset used for national emissions projections.

**6. Conclusions**

Detailed traffic analysis has confirmed the A38 is an important strategic route for north-south journeys and most of the traffic on this road, particularly HGV traffic, uses the road for this purpose (e.g. long range transport between Yorkshire and the Midlands area).

Annual mean NO₂ concentrations across the study area can be understood in terms of a background component and a road component. The background component is around 20 µg/m³ near the A38 Derby, of which approximately 5 µg/m³ is associated with emission sources within Derby. Close to the A38, emissions from the main carriageway are likely to contribute significantly to measured exceedances of the level of the AQS objective (40 µg/m³). These effects are, however, localised and reduce quickly with increasing distance from the A38, such that at the nearest locations of relevant exposure (located >10m from the A38), the AQS objective is unlikely to be exceeded.

Whilst measured exceedances of the annual mean NO₂ AQS objective along the A38 in Derby are most likely due to direct emissions from the volume of traffic on the A38, traffic on the A38 is not, however, the principal cause of the air quality problems in the wider study area. Instead, proximity to the A38 junctions is a significant cause of local air quality problems for the small number of receptors close to these areas. This is due to the elevated emissions on these roads as a result of observed volume flow and congestion during both peak and off-peak periods of traffic.

Reducing emissions from through-traffic on the main carriageway of the A38 would only lead to a small effect on concentrations at the nearest receptors to the road, as these receptors are set back from the A38 (>10 m). The locations with the highest concentrations on arterial roads may experience some air quality improvements the level of congestion on the approaches to these junctions with the A38 could be reduced. The Highways England Derby Junction scheme is regarded as a means to achieve this, as it is expected
that the scheme will reduce emissions associated with congestion along these adjoining arterial roads (the A52, A5111 and A516) and reduce NO₂ concentrations at worst case receptors that are close to the A38 and its junctions in Derby. However, with a programme end date currently set for March 2023 for this improvement scheme, it is not an immediate solution and therefore cannot be treated as a measure that will lead to improvements in air quality in the short term.

The Derby Clean Air Zone (CAZ) could help reduce the proportions of Euro 4 and Euro 5 diesel vehicles in the local vehicle fleet, which would be advantageous as these vehicles are estimated to make the largest contributions to the local road NO₂ component in the study area. It is unclear at this stage, however, what effects (if any) the Derby CAZ may have on traffic flows, as the extent and specification of the CAZ has yet to be agreed. The current plan excludes restrictions for LGVs and private cars which have been shown within this study to be the main contributors to NO₂ concentrations in the study area.