

Greater Manchester's Clean Air Plan to tackle Nitrogen Dioxide Exceedances at the Roadside

Evidence Submission for a new GM Clean Air Plan

Air Quality Modelling Assurance Report



Salford City Council



Oldham Council

TRAFFORD COUNCIL



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1 Purpose of this Document

1.1.1 This document sets out how TfGM has reviewed the modelling processes, to consider any weaknesses in the process, to strengthen the quality assurance (QA) process for these steps and to document the checking/reviewing process.

1.1.2 It also reports the findings of TfGM's Audit & Assurance Team who have audited the updated QA process in place for producing the Clean Air Plan's modelling outputs, primarily in terms of:

- Whether the documented QA process has been applied correctly and in full; and
- Whether there are any obvious gaps or omissions in the QA process, such as lack of segregation of duties and appropriateness of sign-off.

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2 Greater Manchester Clean Air Plan Overview

2.1 Background to the Clean Air Plan

- 2.1.1 In 2017 the Secretary of State (SoS) for Environment, Food and Rural Affairs issued directions under the Environment Act 1995 requiring many local authorities, to produce feasibility studies to identify the option which will deliver compliance with the requirement to meet legal limits for nitrogen dioxide (NO₂) in the shortest possible time. The legal limit being defined as the long-term annual mean legal limit of 40 µg/m³.
- 2.1.2 In Greater Manchester (GM), the ten local authorities, the Greater Manchester Combined Authority (GMCA) and Transport for Greater Manchester (TfGM) are working together to develop a Clean Air Plan to tackle NO₂ exceedances at the roadside, herein known as Greater Manchester Clean Air Plan (GM CAP).
- 2.1.3 The development of the GM CAP is funded by government and is overseen by the Joint Air Quality Unit (JAQU), the joint Department for Environment, Food and Rural Affairs (DEFRA) and Department for Transport (DfT) unit established to deliver national plans to improve air quality and meet legal limits. The costs related to the business case, implementation and operation of the GM CAP are either directly funded or underwritten by government acting through JAQU and any net deficit over the life of the GM CAP will be covered by the New Burdens Doctrine, subject to a reasonableness test¹.
- 2.1.4 In March 2019, the ten GM Local Authorities collectively submitted an Outline Business Case (OBC)² for the GM CAP to JAQU outlining a package of measures to deliver regional compliance with legal limits for NO₂ emissions in the shortest possible time.
- 2.1.5 In July 2019, the Environment Act 1995 (Greater Manchester) Air Quality Direction 2019 was made, which required all ten of the GM local authorities to implement a charging Clean Air Zone Class C³ with additional measures. There was also an obligation to provide further scenarios appraisal information to demonstrate the applicable Class of Charging CAZ and other matters to provide assurance that the local plan would deliver compliance in the shortest possible time and by 2024 at the latest.

¹ The new burdens doctrine is part of a suite of measures to ensure Council Tax payers do not face excessive increases. [New burdens doctrine: guidance for government departments - GOV.UK \(www.gov.uk\)](https://www.gov.uk/government/publications/new-burdens-doctrine-guidance-for-government-departments)

² <https://cleanairgm.com/technical-documents/#outline-business-case>

³ <https://www.gov.uk/government/publications/air-quality-clean-air-zone-framework-for-england/annex-a-clean-air-zone-minimum-classes-and-standards>

- 2.1.6 In March 2020, the Environment Act 1995 (Greater Manchester) Air Quality Direction 2020 was made, which required the submission of an Interim FBC (along with confirmation that all public consultation activity has completed) as soon as possible and by no later than 30 October 2020. The 2020 direction confirmed that legal duty remains to ensure the GM CAP (Charging Clean Air Zone Class C with additional measures) is implemented so that NO₂ compliance is achieved in the shortest possible time and by 2024 at the latest and that human exposure is reduced as quickly as possible. The Ministerial letter accompanying the March 2020 direction confirmed that the minister was satisfied that the main evidence queries from the July 2019 direction had been addressed.
- 2.1.7 A statutory consultation on the proposals took place in Autumn 2020.
- 2.1.8 The GMCA - Clean Air Final Plan report⁴ on 25th June 2021⁵ endorsed GM's Final CAP and policy in compliance with this direction, following a review of all of the information gathered through the GM CAP consultation and wider data, evidence and modelling work. Throughout the development of the previous Plan, the JAQU reviewed and approved all technical and delivery submissions. Within this document, this is referred to as the Previous GM CAP.

2.2 The Previous GM CAP and the impacts of Covid-19

- 2.2.1 Under the Previous GM CAP, GM was awarded £123 million by government for funds aimed at encouraging vehicle upgrades to secure compliance and mitigating the impacts of the GM-wide CAZ. The funds included £15.4 million for bus retrofit, £3.2 million for bus replacement, £10.2 million for Private Hire Vehicles (PHVs), £10.1 million for Hackney Carriages, £7.6 million for Heavy Goods Vehicles (HGVs), £4.4 million for coaches, £2.0 million for minibuses and £70.0 million for Light Goods Vehicles (LGVs).
- 2.2.2 The June 2021 Clean Air Final Plan report set out that the Air Quality Administration Committee (AQAC) had the authority to establish and distribute the funds set out in the agreed GM Clean Air Plan policy. On 21 September 2021 the AQAC approved the establishment and distribution of the agreed bus replacement funds.
- 2.2.3 On 13 October 2021 the AQAC agreed the distribution of Clean Air funds set out in the agreed GM Clean Air Plan policy as follows:
- From 30 November 2021 applications for funding would open for HGVs.
 - From the end of January 2022 applications for funding would open for PHVs, Hackney Carriages, coaches, minibuses and LGVs.

⁴ <https://democracy.greatermanchester-ca.gov.uk/documents/s15281/GMCA%20210621%20Report%20Clean%20Air%20Plan%20-%20FINAL%20FINAL.pdf>

⁵ Also considered by the GM authorities through their own constitutional decision-making arrangements.

- 2.2.4 On 20th January 2022, the AQAC considered the findings of an initial review of conditions within the supply chain of LGVs in particular following Covid-19 related impacts, which were impacting the availability of compliant vehicles and supply-side constraints resulting in price increases, particularly in the second-hand market⁶. The AQAC agreed that a request should be made to the SoS to pause the opening of the next phase of Clean Air Funds. This was to allow an urgent and fundamental joint policy review with government, to identify how a revised policy could be agreed to deal with the supply issues and local businesses' ability to comply with the GM CAP.
- 2.2.5 On 8th February 2022, the AQAC noted the submission of a report "Issues Leading to Delayed Compliance Based on the Approved GM CAP Assumptions". The report concluded that on balance, the latest emerging evidence suggested that with the approved plan in place, it was no longer likely that compliance would be achieved in 2024. Members also requested that arrangements were put in place for those vehicles owners who had already placed orders pending funding opening at the end of January to ensure they are not detrimentally impacted by the decision to pause the opening of the funds. Government subsequently issued The Environment Act 1995 (Greater Manchester) Air Quality Direction 2022⁷ which confirmed that the March 2020 Direction had been revoked and required that by 1st July 2022 the GM authorities should:
- Review the measures specified in the local plan for NO₂ compliance and associated mitigation measures; and
 - Determine whether to propose any changes to the detailed design of those measures, or any additional measures.
- 2.2.6 This Direction ('the Direction') also stated that the local plan for NO₂ compliance, with any proposed changes, must ensure the achievement of NO₂ compliance in the shortest possible time and by 2026 at the latest. It should also ensure that human exposure to concentrations of NO₂ above the legal limit is reduced as quickly as possible.

2.3 The Case for a new GM CAP

- 2.3.1 On 1st July 2022, the AQAC noted that the 'Case for a new Greater Manchester Clean Air Plan⁸ document and associated appendices would be submitted to the SoS as a draft document subject to any comments of GM Authorities.

⁶ <https://democracy.greatermanchester-ca.gov.uk/documents/s18685/ARUP%20Technical%20Note.pdf>

⁷ [The Environment Act 1995 \(Greater Manchester\) Air Quality Direction 2022 \(publishing.service.gov.uk\)](https://www.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/108888/the-environment-act-1995-greater-manchester-air-quality-direction-2022.pdf)

⁸

https://assets.ctfassets.net/tlpgbv1k6h2/7jtkDc5AODypDQlw0cYwsl/67091a85f26e7c503a19ec7aeb2e8137/Appendix_1_-_Case_for_a_new_Greater_Manchester_Clean_Air_Plan.pdf

- 2.3.2 On 17th August 2022, the AQAC agreed to submit the 'Case for a new Greater Manchester Clean Air Plan' to the SoS as a final version and approved the Case for a New Plan - Air Quality Modelling Report for submission to JAQU.
- 2.3.3 The 'Case for a new Greater Manchester Clean Air Plan' set out that challenging economic conditions, rising vehicle prices and ongoing pandemic impacts meant that the original plan of a GM-wide charging CAZ was no longer the right solution to achieve compliance, instead proposing an investment-led, non-charging GM CAP.
- 2.3.4 The primary focus of the 'Case for a new Greater Manchester Clean Air Plan' was to identify a plan to achieve compliance with the legal limit value for NO₂ in a way that considered the cost-of-living crisis and associated economic challenges faced by businesses and residents. This would be achieved through an investment-led approach combined with wider measures that the GM Authorities are implementing and aimed to reduce NO₂ emissions to within legal limits, in the shortest possible time and at the latest by 2026.
- 2.3.5 The 'Case for a new Greater Manchester Clean Air Plan' proposed using the remaining funding that the government has awarded to GM for the Previous GM CAP to deliver an investment-led approach to invest in vehicle upgrades, rather than imposing daily charges, and deliver new Zero Emission Buses (ZEBs) as part of the Bee Network⁹ (a London-style integrated transport network for GM). The new plan would ensure that the reduction of harmful emissions would be at the centre of GM's wider objectives. Within this document, this plan is referred to as the 'Investment-led Plan'.
- 2.3.6 The GM Authorities committed to a participatory approach to the development of the new plan to ensure that the GM Authorities' proposals would be well-grounded in evidence in terms of the circumstances of affected groups and possible impacts of the new plan on them, and therefore the deliverability and effectiveness of that plan.
- 2.3.7 Between August and November 2022, the GM Authorities carried out engagement and research with key stakeholders - vehicle-owning groups and representatives of other impacted individuals, such as community, business, environment and equality-based groups. This activity included targeted engagement sessions with all groups, and an online survey and supporting qualitative research activity with vehicle-owning groups.
- 2.3.8 Input from those engaged informed the ongoing policy development process as the GM Authorities developed the package of measures forming the Investment-led Plan.

⁹ The Bee Network is Greater Manchester integrated transport system joining together bus, Metrolink, rail and active travel <https://tfgm.com/corporate/business-plan/case-studies/bee-network>

2.4 The Investment-led Plan and the impact of bus retrofit issues

2.4.1 Having submitted the 'Case for a new Greater Manchester Clean Air Plan'¹⁰ in July 2022, the GM Authorities were asked by government in January¹¹ 2023 to:

- *Provide modelling results for a benchmark CAZ to address the persistent exceedances identified in central Manchester and Salford, in order for these to be compared against your proposals.*
- *Identify a suitable approach to address persistent exceedances identified in your data on the A58 Bolton Road in Bury in 2025, and to propose a suitable benchmark.*
- *Set out how the measures you have proposed will be modelled and evidenced overall, and to ensure that they are modelled without any unnecessary delay.*

2.4.2 The GM Authorities undertook the work required to supply this further evidence and on 8th March 2023 submitted the report 'Approach to Address Persistent Exceedances Identified on the A58 Bolton Road, Bury'¹². GM Authorities also worked to address the remaining two requests from government by June 2023 on the basis of providing further information to support its Investment-led Plan and testing the proposal against a suitable benchmark CAZ, herein referred to as the 'CAZ Benchmark'.

2.4.3 In April 2023, government advised TfGM that it was to pause any new spending on bus retrofit as it had evidence that retrofitted buses have poor and highly variable performance in real-world conditions¹³. This new evidence followed a JAQU-funded study to quantify nitrogen oxide (NO_x) and NO₂ emissions from buses under real-world driving conditions in three cities across the UK, including Manchester (monitoring took place in Manchester City Centre between 21st November and 12th December 2022). The monitoring indicated that retrofitted buses were not reducing emissions as expected, with significant variation in performance between bus models with retrofit technologies. Furthermore, emissions of primary-NO₂ (as opposed to NO_x) were highly variable, potentially worsening roadside NO₂ concentrations despite an overall reduction in NO_x emissions.

¹⁰

https://assets.ctfassets.net/tlpgbvy1k6h2/7jtkDc5AODypDQlw0cYwsl/67091a85f26e7c503a19ec7aeb2e8137/Appendix_1_-_Case_for_a_new_Greater_Manchester_Clean_Air_Plan.pdf

¹¹ <https://democracy.greatermanchester-ca.gov.uk/documents/s24937/Appendix%201.%20Ministerial%20Letter%20to%20GM%20with%20attachment.pdf>

¹² <https://democracy.greatermanchester-ca.gov.uk/documents/s24939/Appendix%203.%20GM%20CAP%20A58%20Bury%20Measure%20Report%20DRAFT%20for%20AQAC%20Approval%20Feb%202023.pdf>

¹³ <https://democracy.greatermanchester-ca.gov.uk/documents/s27699/Appendix%201.%20Letter%20from%20DfT%20to%20Greater%20Manchester%20regarding%20Bus%20Retrofit%20Update.pdf>

- 2.4.4 Government therefore commenced a six-month focused research programme to quickly investigate the causes of this poor performance and scope how it could be improved, which was anticipated to be reported in Autumn 2023.
- 2.4.5 In the light of government's new evidence, JAQU issued revised general guidance¹⁴ to authorities producing CAPs nationwide. In summary, this required that air quality modelling should no longer assume any air quality benefits from a retrofitted bus.
- 2.4.6 GM incorporated the revised guidance, as agreed with JAQU, into the modelling which underpins the development of its CAP to produce a report that appraises the ability of the Investment-led Plan and the CAZ Benchmark to deliver compliance with the legal limit value in the shortest possible time and by no later than 2026. The key findings from government's six-month focused research programme were not available at the time this work was undertaken.
- 2.4.7 The first version of the *Appraisal Report* and supporting documentation was submitted to government in December 2023. The *Appraisal Report* concluded that GM's Investment-led Plan can deliver compliance in 2025 and performs better than a CAZ Benchmark.

2.5 Key developments since December 2023 submission

- 2.5.1 Since the submission of evidence to JAQU in December 2023 there have been a number of key developments, resulting in a need to update the modelling, the *Appraisal Report* and supporting documentation.
- 2.5.2 Further modelling was undertaken in Summer 2024 to consider and address the following key developments:
- Delay to Stockport all-electric bus depot;
 - Changes to bus fleets (operational and planned); and
 - Correction to Euro V retrofit bus modelling emission values.
- 2.5.3 Drafts of the *Appraisal Report* and supporting documentation were updated to take account of the key developments and the Summer 2024 modelling, in preparation for submission to government. These updates did not change GM's conclusion that the Investment-led, non-charging plan can deliver compliance in 2025 and performs better than a CAZ Benchmark.

2.6 Developments following Summer 2024 modelling

- 2.6.1 Following the substantial drafting to update the *Appraisal Report* and supporting material (to address the key developments since the December 2023 submission), two additional issues have arisen.

¹⁴ Bus Retrofit Update - Technical Guidance for Local Authorities, JAQU Guidance, May 2023

- 2.6.2 Firstly, a risk identified in the December 2023 submission “Delays to bus depot electrification” has materialised and there is now a delivery delay to the electrification of Queens Road depot. This was due to take place by January 2025, which was the assumed delivery date in the modelling of the Investment-led Plan.
- 2.6.3 This poses a significant challenge to achieving compliance in 2025, as 73 ZEBs are to be operated out of Queens Road depot. The issue affects 12 bus services, which run through 17 forecast ‘Do Minimum’ exceedance sites in 2025.
- 2.6.4 Secondly, in July 2024 National Highways also advised TfGM that the temporary speed limit on the M602 is to be removed, and the 70mph speed limit reinstated. The M602 temporary speed limit is assumed to be in place in the Investment-led Plan modelling assumptions.
- 2.6.5 The implications of these two issues are addressed in the Supplementary Appraisal Report, included as part of this evidence submission documentation. Therefore, the Appraisal Report and associated documentation, including this report, should be read in conjunction with the Supplementary Appraisal Report.
- 2.6.6 In addition, since the drafting of the Appraisal Report and supporting material, government published the ‘Bus Retrofit Performance Report’¹⁵ on the 12th September 2024. The key findings of this report include that the retrofit technology fitted onto retrofitted buses is not reducing NOX emissions to the levels expected and retrofit performance is highly variable. These findings are consistent with the guidance issued in May 2023. Therefore, the publication of the study findings has no impact on the Investment-led Plan, the Appraisal Report and supporting material.

¹⁵ <https://assets.publishing.service.gov.uk/media/66e1ab11951c1776394a003c/bus-retrofit-performance-24.pdf>

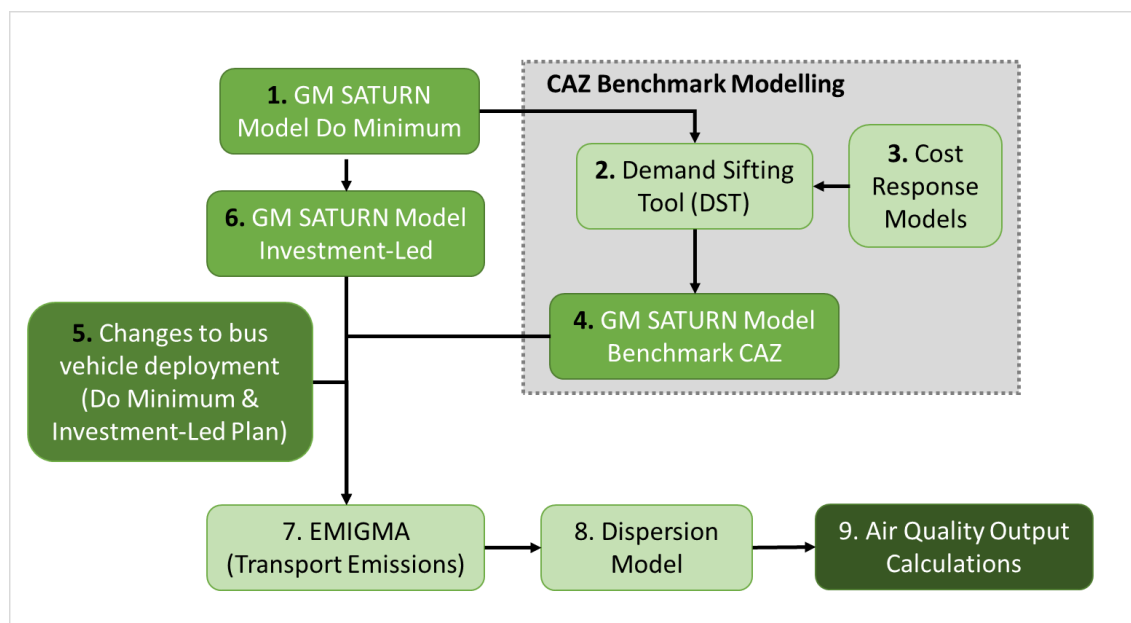
3 GM CAP Modelling

3.1 Modelling Process Context

3.1.1 Modelling processes are based upon input data, relationships and calibrated parameters that come together 'as a model' to produce forecast results. The GM CAP modelling process is a complex series of models that comprises the following components: Modelling processes are based upon input data, relationships and calibrated parameters that come together 'as a model' to produce forecast results. The GM CAP modelling process is a complex series of models. A summary of this process is set out in the figure below and consists of five components:

- **The Greater Manchester highway SATURN model (GMSM)**, which uses information about the road network and travel demand for different years and growth scenarios to estimate traffic flows and speeds for input to the emissions model. The SATURN model also outputs forecast for travel times, distances, and flows for input to the economic appraisal.
- **Cost Response models**, which are models developed to better understand commercial vehicles, taxi, and coach/minibus behavioural changes to the GM CAP. These have been developed by assembling available data on the known fleets and movements within GM (and have been primarily developed to assess the impacts of GM CAP in the context of a CAZ Benchmark).
- **The Demand Sifting Tool (DST)** has been developed to allow measures to be tested in a quick and efficient way prior to detailed assessments being undertaken using the highway and air quality models. The sifting tool uses fleet specific cost response models to determine behavioural responses to the GM CAP proposals (such as pay charge, upgrade vehicle, change mode, cancel trip etc.) The outputs comprise demand change factors which are applied to the Do Minimum SATURN matrices to create Do Something demands for assignment.
- **The emissions model**, which uses TfGM's EMIGMA (Emissions Inventory for GM) software to combine information about traffic speeds and flows (from SATURN) with road traffic emission factors and fleet composition data from the Emission Factor Toolkit (EFT), providing estimates of annual mass emissions for a range of pollutants including oxides of nitrogen (NO_x), primary-NO₂, particulate matter (PM₁₀ and PM_{2.5}) and CO₂.
- **The dispersion model**, which uses ADMS-Urban software to combine information on mass emissions of pollution (from EMIGMA) with dispersion parameters such as meteorological data and topography to produce pollutant concentrations. The outputs of the dispersion model are processed to convert them to the verified air quality concentrations, using DEFRA tools and national background maps.

Figure 1 Overview of Modelling Suite



3.2 Modelling Correction Background

- 3.2.1 In preparation for undertaking sensitivity testing produced to support the GM Clean Air Plan December 2023 submission, an issue was found in the emissions modelling.
- 3.2.2 This has resulted in the amount of primary nitrogen dioxide (NO₂) being under-represented in the model outputs and therefore in the predicted NO₂ concentrations that have been reported in the December 2023 submission for both the with and without scheme scenarios.
- 3.2.3 Regrettably, within TfGM's emissions inventory tool (EMIGMA) a single formula in an Excel spreadsheet tool, that applies a static value for primary-NO₂ (the proportion of NO_x that are released as NO₂ from the tailpipe) in the bus emissions database had not been updated to reference the revised guidance on bus retrofit performance in April 2023 from JAQU (see Appendix 1), following their evidence that bus retrofit solutions from Euro V vehicles have poor and highly variable performance in real world conditions.
- 3.2.4 The issue in the December 2023 submission was that one of the parameters in the EMIGMA database was not updated in April 2023 when a series of revisions to the bus emission factors were made.

- 3.2.5 The original EMIGMA database was compiled by the London Research Centre and RSK Radian on behalf of the Department of the Environment, Transport and the Regions (DETR)¹⁶ for their Air and Environment Quality Research Programme. Released in June 1997, it represented the second of a series of atmospheric emissions inventories covering many of the UK's major urban and industrial zones. TfGM, and predecessor Greater Manchester organisations, have continued to maintain the database and it has been used as part of the annual Local Air Quality Monitoring (LAQM) reporting. At the start of the process, EMIGMA was incorporated into the GM CAP modelling system following a review of the mechanics of the tool by Jacobs (the GM CAP's first Lead Advisor, superseded by ARUP/AECOM in 2019) with several amendments made to the process used to create inputs to the next stage of the process i.e. the ADMS Dispersion Model.
- 3.2.6 Within the development of the GM CAP programme, there are three elements to the application of the modelling system. Two of those elements have included changes which are:
- The data inputs as different scenarios are tested; and
 - Occasionally to the calibrated parameters, as new guidance is issued.
- 3.2.7 The third element of the system, the modelling relationships, has not been changed.
- 3.2.8 The standard QA of the GM CAP forecast data for any given test has been to review the inputs and outputs at each stage of the modelling system to ensure each part of the process has been checked.
- 3.2.9 Checking for changes to calibrated parameters, such as incorporating updates from new versions to Defra's Emission Factor Toolkit, has been undertaken by running external calculations to mirror the input and output emission rates by vehicle type produced by the EMIGMA tool to demonstrate that the tool is functioning as expected. A number of such changes have been made and accurately incorporated into the EMIGMA database. These checks have focused on NO_x emissions and NO₂ concentration outputs following the dispersion modelling step. Knowledge of the change in inputs of a scenario can be used to predict how the scenario outputs should differ from a reference scenario (e.g. the Do minimum) both spatially and by vehicle type due to the revised parameters. The patterns of impacts are reviewed to determine whether the expected impacts had occurred. Occasional issues have been correctly identified using this checking method at various points during the CAP programme and have been corrected.
- 3.2.10 It was this part of the QA process that was not completed accurately enough that has caused the issue in the December 2023 submission.

¹⁶ The UK government department that included what is now known as the Department for Transport

- 3.2.11 Up to April 2023, retrofit buses (Euro IV or V) in the GM fleet were represented in the EMIGMA database as Euro VI buses as per Defra/JAQU guidance i.e. retrofitting technology assumed to improve vehicle emissions to meet the Euro VI standards. This was the standard practice recommended by Defra/JAQU.
- 3.2.12 The revised JAQU guidance issued in April 2023 (see Appendix 1) altered two factors. The guidance stated:
- Firstly, that there are no improvements to NO_x emissions to be expected from retrofitted buses, and so NO_x emissions should be those for a relevant pre-retrofit Euro standard of bus; and
 - Secondly, that the primary-NO₂ fraction should be increased from the NAEI value of 8% to 35.8%.
- 3.2.13 While issuing the revised guidance, JAQU informed that they had commissioned a further research programme to improve the underpinning evidence base for the new guidance, which would report in six months, with the expectation that this further research may alter the guidance again.
- 3.2.14 The GM CAP team undertook to make the changes to alter the two factors, and, once these changes were believed to have been implemented, the usual checks were run. These checks showed that the increase in NO_x emissions from buses were as to be expected for a change from a Euro VI standard to a Euro V standard, and the differential spatial pattern could be observed where known electric buses were operating (the 43 and 111 services). However, because the aggregate NO_x emissions had increased, this result masked the effect on the final NO₂ concentrations. While the NO₂ concentrations had as expected also increased, the increase was not by as much as it should have been if the proportion of primary NO₂ had also been increased. This was the correction which has now been resolved.
- 3.2.15 The context for this was that the updated JAQU guidance on bus retrofit was received at a point in the CAP programme when GM were due to submit their 'final plan' approval. The new guidance on retrofit performance required the GM CAP team to undertake a rapid assessment of the implications of the updated guidance on the outcomes of the 'final plan' to inform whether the submission needed to be postponed.
- 3.2.16 The rapid assessment involved:
- Making revisions to the model parameters as per the new April 2023 guidance and running the usual checks – where the failure to revise the NO₂ parameter was not identified;
 - A review of the evidence underpinning new JAQU guidance, particularly given the knowledge that further research was underway that was likely to change the guidance again;

- The development of a proposal that GM should produce its own guidance on parameters based on new analysis of the raw research dataset, which was subsequently formally offered and proposed by JAQU; and
- Re-running the full model system to re-test the 'final plan' and the commissioning of technical work required to revise the plan.

3.2.17 In hindsight, the GM CAP technical team's focus on the latter three tasks contributed to an oversight in checking the revisions to the EMIGMA database. In context that the following factors occurred in tandem:

- High workloads as a result of the updates to the GM CAP programme;
- Uncertainty on the finality of the guidance itself; and
- The standard QA process showing plausible results at a high-level.

3.2.18 The factors meant that appropriate time was not taken to pause to reflect on the nature of the changes that needed to be applied into the EMIGMA database. On reflection, the error highlighted the need to strengthen the QA process to revise the external calculations of the EMIGMA NO₂ emissions outputs.

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4 Revised Assurance Process

- 4.1.1 TfGM has identified that a revised assurance process is required for the GM CAP modelling and appraisal, with the steps undertaken set out below.
- 4.1.2 The Data Evidence and Modelling (DEM) Team have, with TfGM's Head of Modelling & Analysis, reviewed their QA processes, identifying gaps/weaknesses and then have set out a workflow process, which identifies the data sources, modelling steps, data transfers between internal/external teams and outputs. Each of these steps has been reviewed to consider any weaknesses in the process, to formally describe the QA process for these steps and to document the checking/reviewing process.
- 4.1.3 As part of this review process, it has been noted that the project has altered over time, as the focus of the likely intervention or measures have changed from CAZ-based options, to the appraisal of investment-led options (bus, taxi and local traffic management), alongside updating of reference data sources such as ANPR data and bus fleet information.
- 4.1.4 Prior to the discovery of the modelling error, the QA processes have been undertaken and documented internally within consultant/TfGM teams on a scenario-by-scenario basis. Following the assurance review, a centralized log of checks and reviews have been developed for each modelled scenario. Currently, the modelling run log containing the test scenario assumptions/inputs. This will be extended to include the QA record sign-off and date, to enable a more readily auditable start to finish process before results are approved to be shared beyond DEM/TfGM.
- 4.1.5 At each point or scenario where a modelling tool needs to be updated, the QA process and log will be reviewed, to ensure that necessary checks and procedures are applied.
- 4.1.6 TfGM's Audit & Assurance Team have audited the completeness of the QA process of the modelling analysis that underpins the Clean Air Plan submission. Review of documentation has been completed as per the documented QA process.

5 Internal Assurance Team Report Findings

5.1.1 TfGM's Audit & Assurance Team's findings were as follows:

Discussions and walk-through with members of the DEM team confirmed their understanding of the source of the original error and why this had occurred. Positively, the DEM team were able to demonstrate that this had been corrected in the latest models.

The key control document that evidences the agreed assurance approach and checks undertaken by the DEM team for the required five separate scenarios is the 'QA Process Checks' Technical Note. We found the document to be fit for purpose; for each step of each stage, there is a narrative description of the checks carried out with a link to the relevant spreadsheet or output. The document records who performed the initial check and who acted as the approver / technical check. In addition, there is also a column for a separate non-technical verifier to record their separate, independent check thus providing a segregation of duties control.

Our review of the use of 'QA Process Checks' Technical Note by the DEM team found that it was properly completed by them, with two people involved in checking each step in the iterative modelling process, including an 'originator' and an 'approver (technical checks)'. In addition, a 'verifier (non-technical)' had signed off on each step. Lastly, the header of the document showed overall approval by TfGM's Head of Modelling & Analysis.

We also reviewed the 'Key Metrics Check' document which summarises the key inputs, assumptions, and outputs for each stage of the modelling process for each of the five scenarios. This document provides a simple audit trail of the evolution of the models, showing how the outputs from one stage become the inputs of the next. Against each entry, a member of the DEM team who has acted as the 'checker' has added brief comments to point to the source of the data, to highlight where results are consistent with expectations, or to explain the reasons for any small variations. Similar to the above, this document has a 'sign off' box which indicates that the AECOM Regional Director has 'verified' the figures, followed by approval by TfGM's Head of Modelling & Analysis.

Together with the relevant member of the DEM team, we sample tested at least one scenario for each step/stage from this document, tracing the figures provided back to the source documents. All sampled figures reconciled with the source files.

We were also shown how key model outputs are tracked in the 'GMCAPModelRunLog', which records each test/scenario code, a brief description, and total emissions. The purpose of this is to track changes between each run and also act as a 'sense check' – i.e. ensuring that a change to one individual parameter results in an expected impact on emissions.

Based on our work undertaken, as described above, we are able to provide assurance that the QA process for the Clean Air Plan Modelling work has been completed in full and documented. Segregation of duties was evidenced by at least two members of the team involved in the process, as well as a 'Verifier (Non-technical)' checker and final sign-off.

An important caveat to note is that our work cannot be taken as assurance over the accuracy or correctness of the modelling itself, as this is beyond our remit and expertise. In addition, though we were able to trace key figures back to source documents, we cannot with certainty confirm that these are the correct source documents given the scale of the project and large number of distinct modelling runs. Rather, we place reliance on the QA process wherein the team have collectively checked, verified, and signed off on the figures.

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Appendix 1: Primary Nitrogen Dioxide and Bus Retrofit

In 2022, JAQU funded a study to quantify NO_x and NO₂ emissions from buses under real-world driving conditions in three cities across the UK, including Manchester, with monitoring taking place in Manchester City Centre between 21 November and 12 December 2022. This survey concluded that:

- genuine (i.e. non-retrofit) Euro V and Euro VI buses were producing emission rates that are consistent with known emissions performance, with relatively low variability between vehicle type (such as manufacturer and vehicle size)¹⁷.
- the retrofitted buses were not reducing emissions as expected, with significant variation in performance between different bus models with different types of retrofit technologies, with, emissions of primary NO₂ (as opposed to NO_x) being highly variable, potentially worsening roadside NO₂ concentrations despite an overall reduction in NO_x emissions.
- emissions from retrofit vehicles varied significantly between vehicles - on average retrofit buses produced a small reduction in emissions compared to an average Euro VI, but the variation in measured emissions from retrofit buses was very high ranging from almost Euro VI performance to worse than the average Euro V results; and
- the proportion of primary NO₂ emitted is much greater from retrofitted vehicles and f-NO₂ of 35.8% for emissions from retrofitted buses should be assumed.

In April 2023 the government advised TfGM that it was to pause any new spending on bus retrofit as they now had evidence that bus retrofit solutions, which had already been fitted, were having poor and highly variable performance in real world conditions.

The 'Bus Retrofit Performance Report'¹⁸ was published by the Department of Transport in September 2024 which states the following:

“Overall, the monitoring campaigns in Manchester and Sheffield suggest that the SCR technology on retrofitted buses is not, in the sample studied, reducing NO_x emissions to the levels expected. The variation in median emissions and the interquartile ranges show that retrofit performance is highly variable”.

¹⁷ A Euro VI bus reduces NO_x emissions by c90% compared to a Euro V. Both Euro V and Euro VI buses have low proportions of NO_x emitted as NO₂ (or primary NO₂). Primary NO₂ is important because an increase leads to a greater NO₂ concentration at roadside where air quality standards are measured and apply.

¹⁸ <https://assets.publishing.service.gov.uk/media/66e1ab11951c1776394a003c/bus-retrofit-performance-24.pdf>