Greater Manchester's Clean Air Plan to tackle Nitrogen Dioxide Exceedances at the Roadside: Option for Consultation

Note T4 Appendix A: Behavioural Response Cost Models and Demand Sifting Tool

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COVID-19 Pandemic Statement

This work has not considered the impact of the COVID-19 pandemic. Whilst we are continuing, where possible, to develop the Greater Manchester Clean Air Plan, the pandemic has already had an impact on our ability to keep to the timescales previously indicated and there may be further impacts on timescales as the impact of the pandemic becomes clearer.

We are also mindful of the significant changes that could result from these exceptional times. We know that the transport sector has already been impacted by the pandemic, and government policies to stem its spread. The sector's ability to recover from revenue loss, whilst also being expected to respond to pre-pandemic clean air policy priorities by upgrading to a cleaner fleet, will clearly require further thought and consideration.

The groups most affected by our Clean Air Plan may require different levels of financial assistance than we had anticipated at the time of writing our previous submission to Government.

More broadly, we anticipate that there may be wider traffic and economic impacts that could significantly change the assumptions that sit behind our plans. We have begun to consider the impacts, and have committed to updating the government as the picture becomes clearer over time.

We remain committed to cleaning up Greater Manchester's air. However, given the extraordinary circumstances that will remain for some time, this piece of work remains unfinished until the impact of the COVID-19 pandemic has been fully considered by the Greater Manchester Authorities.

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1 Introduction

1.1.1 In July 2017 the Government published the UK plan for tackling roadside nitrogen dioxide (NO_2) concentrations. This set out how the Government would bring UK concentrations of NO_2 within the statutory annual limit of 40 micrograms per cubic metre ($\mu g/m^3$) in the shortest possible time. The plan sets out several national and local measures that needs to be taken.

1.1.2 The ten Greater Manchester authorities have asked Transport for Greater Manchester (TfGM) to develop the Greater Manchester (GM) Clean Air Plan (CAP) on their behalf.

1.1.3 T4 Appendix A provides a description of two key areas of the modelling suite for the GM CAP, these are:

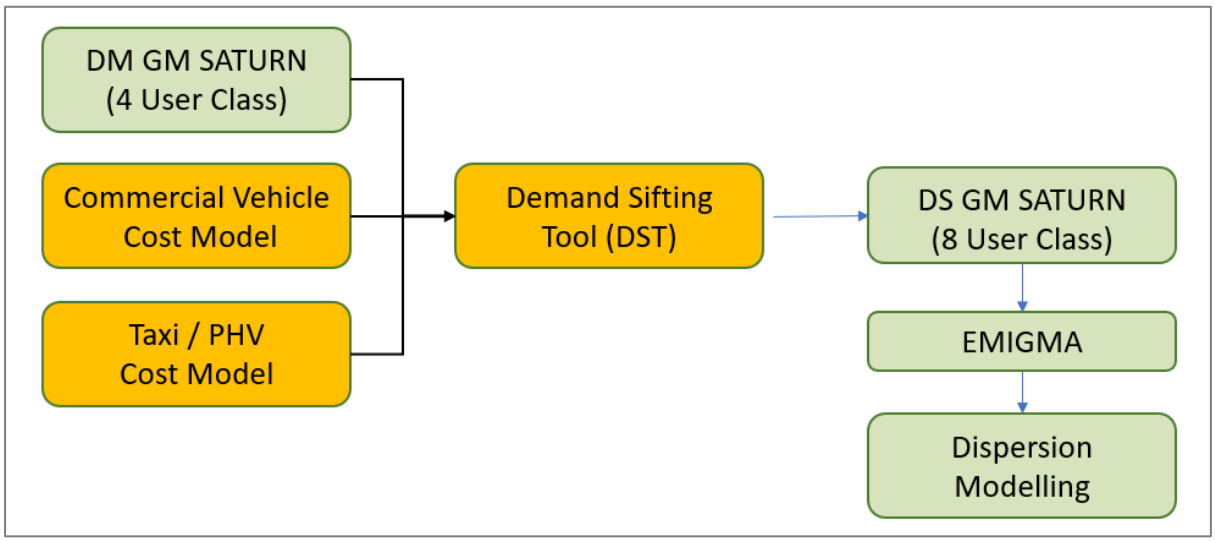
- The development of cost models for Commercial Vehicles and Taxis, to understand the expected behavioural responses due to the GM CAP; and
- The development and use of a Demand Sifting Tool (DST) to apply the behavioural responses, understand the expected changes in vehicle volumes, specifically the change from non-compliant to compliant vehicles, plus the application of a change mode response, where appropriate.

1.1.4 The sections below explain the development of these tools, discussing the key inputs, calculations, and model outputs.

1.2 Overview of Modelling Suite

1.2.1 An overview of the modelling process is shown in **Figure 1-1**, though the focus of T4 Appendix A is the Behavioural Response Cost Models and the Demand Sifting Tool (DST).

Figure 1-1 Flowchart summarizing the modelling process



1.3 Behavioural Responses Overview

1.3.1 At OBC a range of methods were used to inform the behavioural responses to the CAZ charges, including data from stated preference surveys. However, these surveys were not local to Greater Manchester and did not reflect local operating conditions. Behavioural responses for hackney cabs and HGVs could not be derived from the survey data. A series of cost models were developed to better understand the behavioural responses to the CAZ and the likely impact of proposed funds.

1.3.2 The following models were developed:

- **Commercial Vehicles Cost Model** - capturing behavioural responses for HGVs and LGVs;
- **Taxi Vehicle Cost Model** – capturing the behavioural responses for Hackneys and PHVs; and
- **Coaches / Minibus Cost Model** – Capturing the behavioural responses for Coaches and Minibuses (note this model does not inform the DST – so is not covered by T4 Appendix A).

1.3.3 Chapters two and three provide a detailed description of the Commercial Vehicles and Taxi cost models.

1.4 Demand Sifting Tool Overview

1.4.1 The Demand Sifting Tool (DST) has been developed as part of the GM CAP to test various options with the aim of finding the key measures that could tackle NO_2 concentrations and improve air quality in the shortest possible time.

1.4.2 The purpose of the DST is to provide a relatively quick and efficient way of assessing the likely impact of potential measures to improve air quality at key areas in Greater Manchester, making use of tools that TfGM already have access to such as their County Wide SATURN highway model.

1.4.3 The DST is discussed in detail in **Chapter 4**.

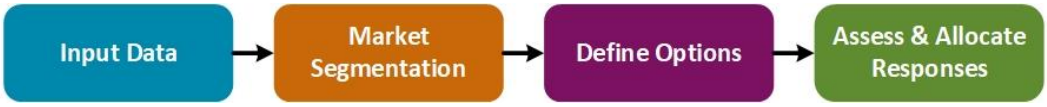
2 Commercial Vehicles Cost Model

2.1 Model Overview

2.1.1 At OBC, the predicted CAZ behavioural responses of LGV drivers were derived from SP surveys, which were reviewed in the context of the Greater Manchester CAP. There were no surveys available for HGVs and responses were derived from values provided by JAQU and sourced elsewhere. For hackney cabs, due to the lack of survey data, a simple assumption was made that all vehicles would upgrade. There were also concerns about the reliability of SP survey data for commercial vehicles. As an alternative to these surveys, and in the absence of local Greater Manchester based SP surveys, TfGM has developed a response model (the model) in order to test how commercial vehicle (HGV and LGV) owners would react to the proposed Clean Air Zone (CAZ) charge. This section provides a description of the development of the model, outlining the methodology and key assumptions incorporated in the tool. The results produced by the model are a series of behavioural responses to the introduction of the CAZ and also the proposed funds.

2.2 The structure of the model from input data through to the vehicle owner responses is outlined in **Figure 3-1** and discussed below.

Figure 2-1 Model methodology



2.3 Input Data

2.3.1 The inputs included a data set of registration plates captured by ANPR cameras in 2019 and vehicle registration lists for Greater Manchester published by the Driver and Vehicle Licensing Agency (DVLA). **Figure 2-2** outlines the methodology for how the input data was estimated while **Table 2-1** displays the figures used.

Figure 2-2 Commercial vehicles input data

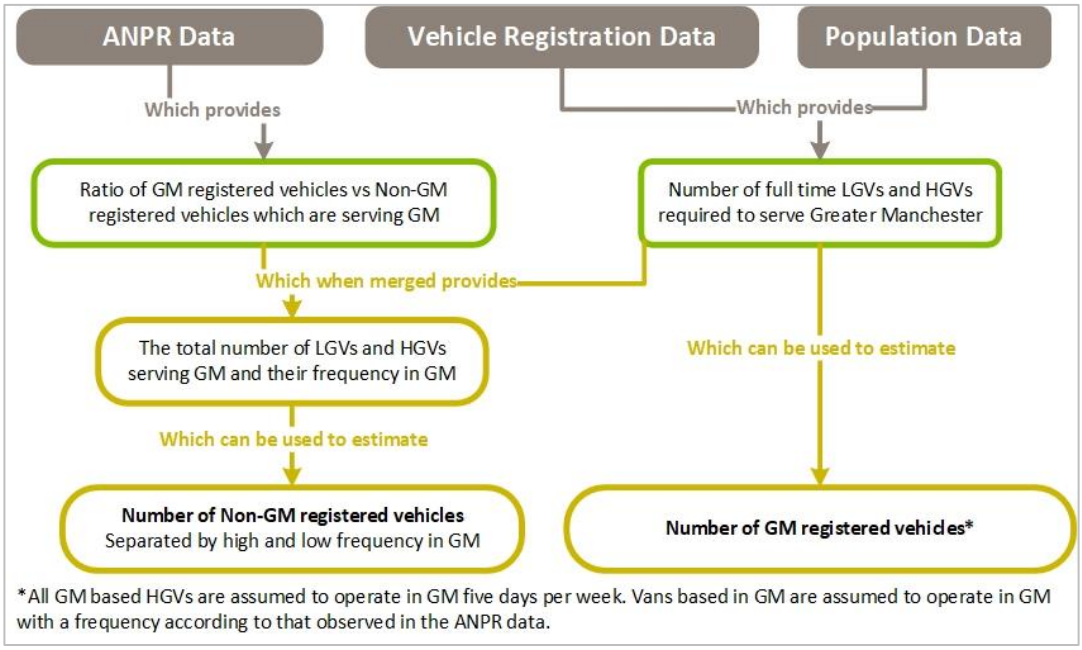


Table 2-1 Commercial vehicles input data (non-compliant vehicle numbers at CAZ implementation shown in brackets)

	LGVs [2023] (non-compliant)	HGVs [2021] (non-compliant)
GM registered	135,700 (75,400)	25,700 (7,400)
Registered outside of GM	141,700 (54,900)	45,100 (9,300)
Total	**277,400 (130,300)**	**70,800 (16,700)**

2.4 Market Segmentation

2.4.1 Segmenting the market allows the model to allocate vehicle owners to different decisions/responses. The 'right' level of segmentation depends on the data available (in order to estimate the proportion of the market belonging to each segment) as well as how strongly different divisions of the market vary in their operations/types. For this model, the market was segmented into the characteristics shown in

2.4.2 **Table** 2-2.

Table 2-2 Market segmentation

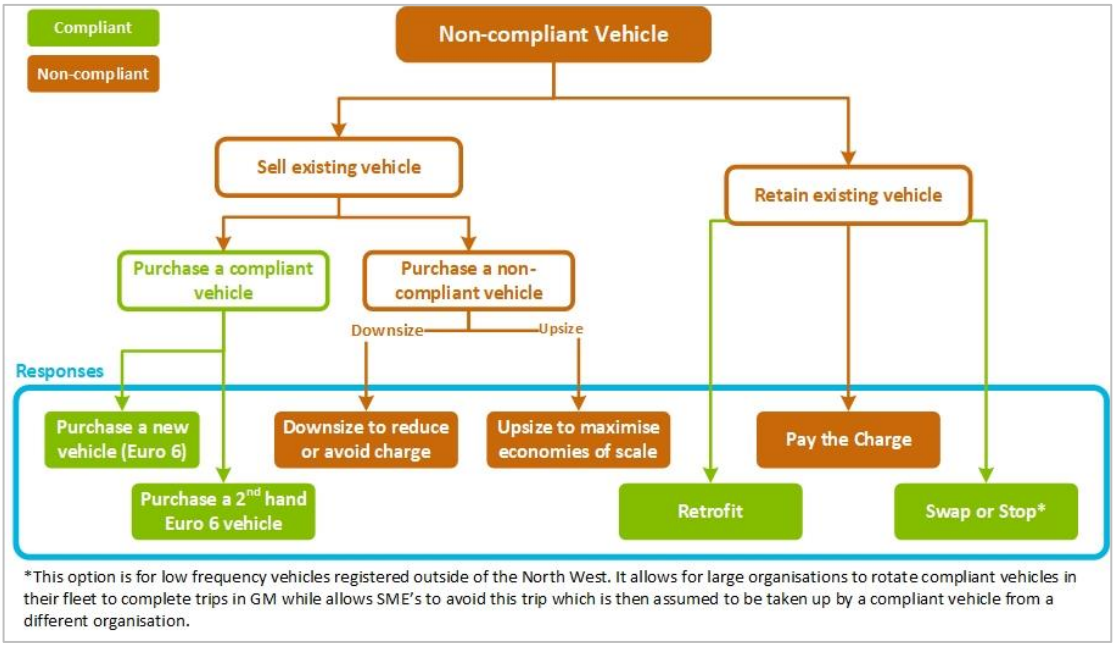
Characteristics	Segments	Source
Vehicle registration location	• Greater Manchester • North West	ANPR data

	• Other	
Frequency (in GM)	• Low • High	ANPR data
Vehicle type	• Based on gross weight: – 1.6 t (LGV) – 3.5 t (LGV) – 7.5 t (HGV) – 18 t (HGV) – 26 t (HGV) – 32 t (HGV) – 44 t (HGV – Artic)	ANPR data
Vehicle ownership	• SME • Large organisation	Department for Transport (Van Statistics) and Consultant opinion
Sector	• HGVs (9 sectors) • LGVs (16 sectors)	Special Goods Vehicle Count survey (based in London) for HGVs and SMMT sector distribution for LGVs
Vehicle age	• New to 23 years old	ANPR data

2.5 Define Options

2.5.1 A list of possible responses to a CAZ has been identified which aims to capture a high percentage of the actual responses from the market. The responses/options available to vehicle owners that have been included in the model are shown in **Figure 2-3**.

Figure 2-3 Commercial vehicle owner options



2.5.2 Depending on the characteristics of the vehicle owner, some options have been assumed to be unfeasible. The following assumptions based on industry experience of the GM market were made regarding available options:

- Retrofit is not available. In reality, a retrofit option is likely to be available and a feasible option for certain makes of vehicle however the model does not disaggregate vehicles to manufacturer/make level. It can however be used to test the attractiveness of retrofit schemes for indicative purposes. At present, the retrofit market covers a very small proportion of commercial vehicles operating in GM.
- Only SMEs are assumed to purchase second hand vehicles. Large organisations are assumed to only purchase brand new vehicles when upgrading.
- Only SMEs are assumed to consider downsizing from a 1.6 tonne van to an estate car to avoid the charge.
- The 'Swap or Stop' option is only available to vehicles registered outside of GM. Large organisations are assumed to have compliant vehicles in their fleet which can be 'swapped' in place of the non-compliant vehicle for GM trips if they are of low frequency. Vehicles of low frequency in GM belonging to SMEs that are based outside of the North West are assumed to 'stop' these trips which will then be absorbed by a compliant vehicle.

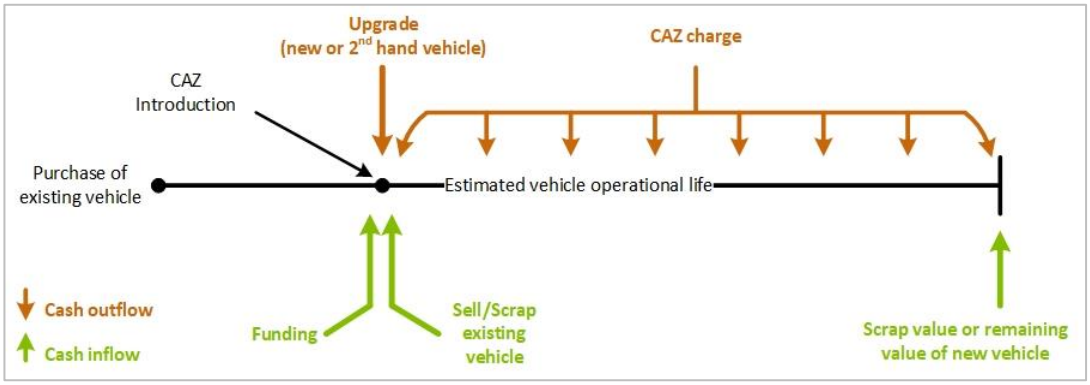
2.6 Assess & Allocate Responses

2.6.1 Each market segment was allocated to an option based on which was estimated to be the best financially for the vehicle owner. The cost/value of each option was determined using a discounted cash flow model which is illustrated in **Figure 2-4**. The cash flows included in each option are shown in **Table 2-3**. The cost response models operate on a 'value' based approach, meaning that responses are based on which option presents the most value to the vehicle owner. It is assumed that the grants and vehicle finance packages proposed enable vehicle owners to achieve compliance via their preferred response to the charge.

Table 2-3 Cash flows included for each option available

Option	Sell existing vehicle	Purchase compliant vehicle	Purchase Retrofit	Funding	CAZ Charge	Remaining vehicle value
Do nothing (pay the charge)					✓	✓
Upgrade vehicle	✓	✓		✓		✓
Retrofit existing vehicle			✓	✓		✓

Figure 2-4 Schedule of cash flows for assessing options



2.7 Key evidence and assumptions review

2.7.1 This section aims to review the key evidence and assumptions incorporated in the model. It is worth noting that those assumptions are based on the best available knowledge and existing data.

Vehicle data and categorisation

2.7.2 It is important to recognise that different vehicle owners will make different decisions based on multiple factors. A week's worth of data had been collected by ANPR cameras installed in multiple locations in GM, which provides the model with a large sample size and key information such as vehicle ages, types and weights.

2.7.3 All vehicles recorded by the cameras are categorised into groups based on organisation size, commodity sector, vehicle size and vehicle age.

2.7.4 LGVs are categorised into different commodity sectors based on proportions provided by a recent report[1] issued by The Society of Motor Manufacturers & Traders (SMMT) in 2019. HGVs are categorised into corresponding sectors based on results of Specialised Goods Vehicle Counts (SGVC) conducted by AECOM's freight team in London, though have since been sense checked against local research within Greater Manchester and have been shown to be conisistent.

2.7.5 According to the SMMT, vehicles purchased from new tend to be de-fleeted after a certain age from large organisations and the majority of second and third life vehicles are typically operated by SMEs. Therefore, vehicles are further categorised into "SMEs" and "Large Organisations" based on vehicles age profile.

Sector and replacement age

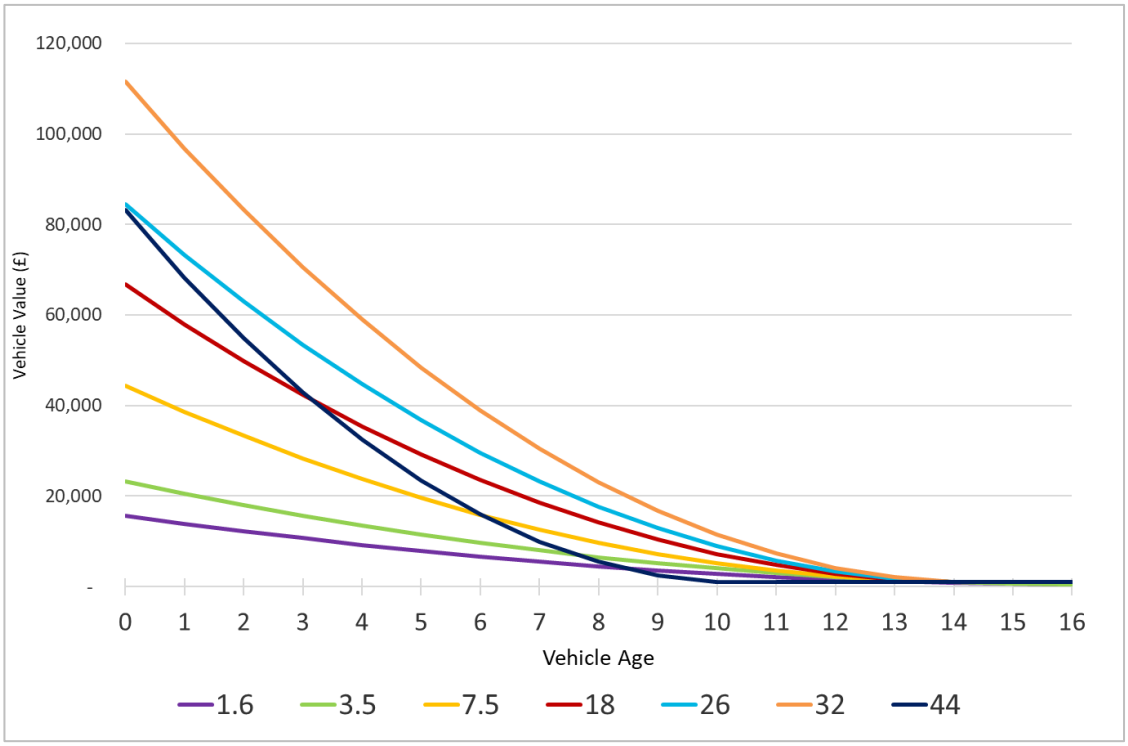
2.7.6 Based on the commodity sectors, the replacement ages are varied for both LGVs and HGVs. For example, the construction sector tends to keep vehicles until they are much older than those in the financial sector. The average age at which vehicles are scrapped was estimated from the ANPR data. Sector scrapping ages are based from this market average.

Vehicle values and depreciation

2.7.7 Vehicle purchasing and remaining values are key parts of the cash-flow cost model. **Figure 2-5** displays the vehicle purchasing values, based on weight categories varying from 1.6t to 44t, acquired from a Cost Table[2] published by Motor Transport in 2018. Depreciated values along vehicle lifetimes are incorporated in the model using a double-declining-balance depreciation method. The depreciation rate shown in the figure represents that vehicle values depreciate considerably during the early stage of usage and gradually become steadier when approaching the end of the vehicle's life. The value of a typical estate car is also incorporated in the model acquired from Auto Trader data.

[1] Light Commercial Vehicles Delivering for The UK Economy 2019 report
[2] https://motortransport.co.uk/wp-content/uploads/2018/12/MT-cost-tables-2018.pdf

Figure 2-5 Freight vehicle values



2.7.8 When modelling whether non-compliant vehicle owners will choose to upgrade to a new vehicle or a used compliant vehicle, the following information was used as part of the process. LGV owners will typically fall into either the new or used van ownership market. Vehicle owners who buy new LGVs will typically operate them for 4-5 years before trading them in to a dealer for a new vehicle due to the reduced operating and maintenance costs of new vehicles as well as the increased reliability and reputational benefits of operating new vehicles. Vehicle owners in the used market will buy 4-5 year old vehicles from a dealer and either operate them for an additional 5-6 years before selling them privately to a 3rd owner (typically a micro business or sole trader) or operating them themselves until they are scrapped. The HGV market acts in a similar way however the life of a HGV is shorter and thus there is less of a 3rd hand market. To reflect these characteristics in the cost response models, the following assumptions have been applied:

- Large organisations are assumed to purchase new vehicles only; and
- Small and Micro businesses, as well as Sole Traders, are assumed to purchase second hand complaint vehicles unless their existing vehicle is less than 4 years old, in which case they are assumed to purchase new vehicles.

Vehicle utilisation (operating days)

2.7.9 It is assumed that LGVs are operated 5 days a week and 46 weeks per year, however for HGVs it is assumed that the vehicles are operated with a slightly higher intensity. The number of days per year that HGVs are assumed to operate is 253 which is in line with JAQU's recommendation.

2.8 Model limitations

Impacts of market distortion

2.8.1 The vehicle values shown in **Figure 2-5** represent the existing market and do not consider what the implementation of the CAZ will do to vehicle values and costs. It is likely that the value of compliant second-hand vehicles will significantly increase while the value of non-compliant vehicles (i.e. Euro V engines) will decrease. The magnitude of these changes in value will depend on local market access to the broader national market and the extent and nature of CAZ implementation in other areas around the country.

Consideration of operation costs and revenues (profit margins)

2.8.2 The operational revenue or profit margins of the companies are not considered as part of the model. This is a limitation as it does not allow for more accurate representation of the benefits/costs from downsizing or upsizing options.

2.8.3 The model is based on the assumption that businesses will make the best value for money choice. This does not take into account the possibility that they may not have the funds or access to finance available to allow them to make this choice. This is likely to be more of an issue for smaller businesses and means that the benefits of grants or subsidised loans are likely to be under-estimated.

2.8.4 As with all such models, the assumption is made that vehicle owners have access to accurate information about the costs of different aspects and make a rational choice based on the relative costs of each option.

2.8.5 Despite not including these dimensions, the overall approach is fit for purpose and represents a significant improvement in our understanding of the GM commercial vehicle market and the likely impact of the CAP.

2.9 Model Outputs

2.9.1 The model has produced a set of responses for a base case with-CAZ scenario (no funding) as well as a funding scenario for CAZ implementation years of 2021, 2023, and 2025 for both HGVs and LGVs (noting for LGVs an exemption is assumed until 2023). These results form the basis of the response input to the DST.

2.9.2 The inputs to the DST are shown in the section below, where 'Change Mode' refers to when vehicle owners might upsize of downsize to a compliant vehicle. (for example, a change from an LGV to an Estate Car or from a HGV to an LGV). Charges for LGVs and HGVs are assumed to be £10 and £60 per day respectively.

HGV Behavioural Responses

2.9.3 Table 2-4 shows the HGV behavioural responses for the 'CAZ Only' output of the Commercial vehicle cost model.

Table 2-4 'CAZ Only' (£60 charge): HGV Behavioural Responses

Modelled Response	2021	2023	2025
Pay Charge	2.8%	4.8%	1.9%
Change Mode	0.2%	0.0%	0.0%
Cancel Trip	0.0%	0.0%	0.0%
Upgrade	97.0%	95.2%	98.1%

Source: HGV Cost Response Model

2.9.4 The pattern of response across the years reflects that the age profile of the fleet is not a smooth distribution and takes account of the estimated change in the cost of second-hand compliant vehicles over time. This, alongside the fact that the three years tested are modelled separately, results in what at first appears to be counter intuitive changes in the 'pay charge' response from 2021 through to 2025. In reality, we would expect to see a smoother progression towards increasing compliance.

2.9.5 For the 'CAZ plus funds' scenario, where some financial assistance is available to drivers, assuming certain eligibility criteria, the funding for HGV upgrades varies by weight category and requires vehicle scrappage to access the funds. The assumed funding assistance available by weight category is:

- 7.5t = £2,500;
- 18t = £3,500;
- 26t = £4,500; and
- 32t = £5,500.

2.9.6 **Table 2-5** below provides the outcome from the 'CAZ plus funds' result.

Table 2-5 CAZ (£60 charge) plus funds: HGV Behavioural Responses

Modelled Response	2021	2023	2025
Pay Charge	2.7%	4.8%	1.9%
Change Mode	0.1%	0.0%	0.0%
Cancel Trip	0.0%	0.0%	0.0%
Upgrade	97.2%	95.2%	98.1%

Source: HGV Cost Response Model

2.9.7 The impact of the funds forecast by the cost model is clearly limited but this does not mean that there are no real-world benefits to be gained, particularly for small operators, because the modelling simplifies the variety of vehicles and their value, removing the full range of variables operators consider. Also, the modelling does not take into account whether operators have the equity or credit available to make the upgrade, which would be in some part resolved by the provision of a grant or subsidised loan.

LGV Behavioural Responses

2.9.8 **Table 2-6** below shows the behavioural responses for the 'CAZ Only' result for LGVs from the Commercial vehicles cost model.

Table 2-6 'CAZ Only' (£10 charge): LGV Behavioural Responses

Modelled Response	2021	2023	2025
Pay Charge	*Not Applicable (LGVs exempt until 2023)*	30.1%	26.8%
Change Mode		4.6%	0.0%
Cancel Trip		0.0%	0.0%
Upgrade		65.3%	73.2%

Source: LGV Cost Response Model

2.9.9 For the 'CAZ plus funds' scenario, the funding available for LGV upgrades is as follows:

- £3,500 for all eligible LGVs and requires vehicle scrappage to access the funds.

2.9.10 **Table** 2-7 below provides the findings from the CAZ plus funds model run, showing considerable benefits in terms of deterring a 'stay and pay' response and reducing the numbers downgrading to an estate car.

Table 2-7 CAZ plus funds: LGV Behavioural Responses

Modelled Response	2021	2023	2025

Pay Charge	*Not Applicable (LGVs exempt until 2023)*	12.2%	13.6%
Change Mode		3.4%	0.0%
Cancel Trip		0.0%	0.0%
Upgrade		84.5%	86.4%

Source: LGV Cost Response Model

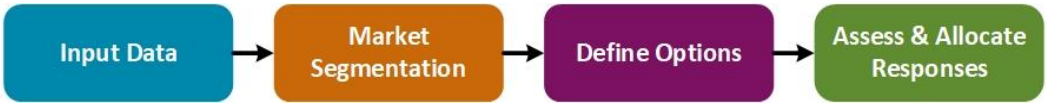
3 Taxi Cost Model

3.1 Model Overview

3.1.1 At OBC, the CAZ behavioural responses for private hire vehicles were derived from SP surveys, which were reviewed in the context of the GM CAP. A simple assumption was made that all hackney cabs would upgrade, in the absence of available information on likely behavioural responses. As an alternative to these surveys, and in the absence of local GM SP surveys, TfGM has developed a response model (the model) in order to test how taxi drivers would react to the proposed Clean Air Zone (CAZ) charge. This section provides a description of the development of the model, outlining the methodology and key assumptions incorporated in the tool. The results produced by the model are a series of behavioural responses to the introduction of the CAZ and also the proposed funds.

3.2 The structure of the taxi cost model from input data through to the vehicle owner responses is outlined in **Figure 3-1** and discussed below.

Figure 3-1 Model methodology



3.3 Input Data

3.3.1 The inputs available to the model to determine the number of vehicles that would be impacted by the CAZ (i.e. the number of vehicles operating in GM) include a data set captured by ANPR cameras over a one-week survey and vehicle licensing lists by Local Authority. Using the assumption that all vehicles licensed in GM choose to operate in GM, the vehicle licensing data provides the number of traditional black taxis (Hackneys), 'Non-London' Hackneys (NL Hackneys), i.e. vehicles which operate as Hackneys but are not the traditional TX4 body type and private hire vehicles (PHV) operating in GM that are also licensed in GM. What remains unknown is the number of vehicles operating in GM that are licensed elsewhere. **Figure 3-2** outlines how this was estimated. The resulting number of vehicles which are modelled is outlined in **Table 3-1**.

Figure 3-2 Data input process

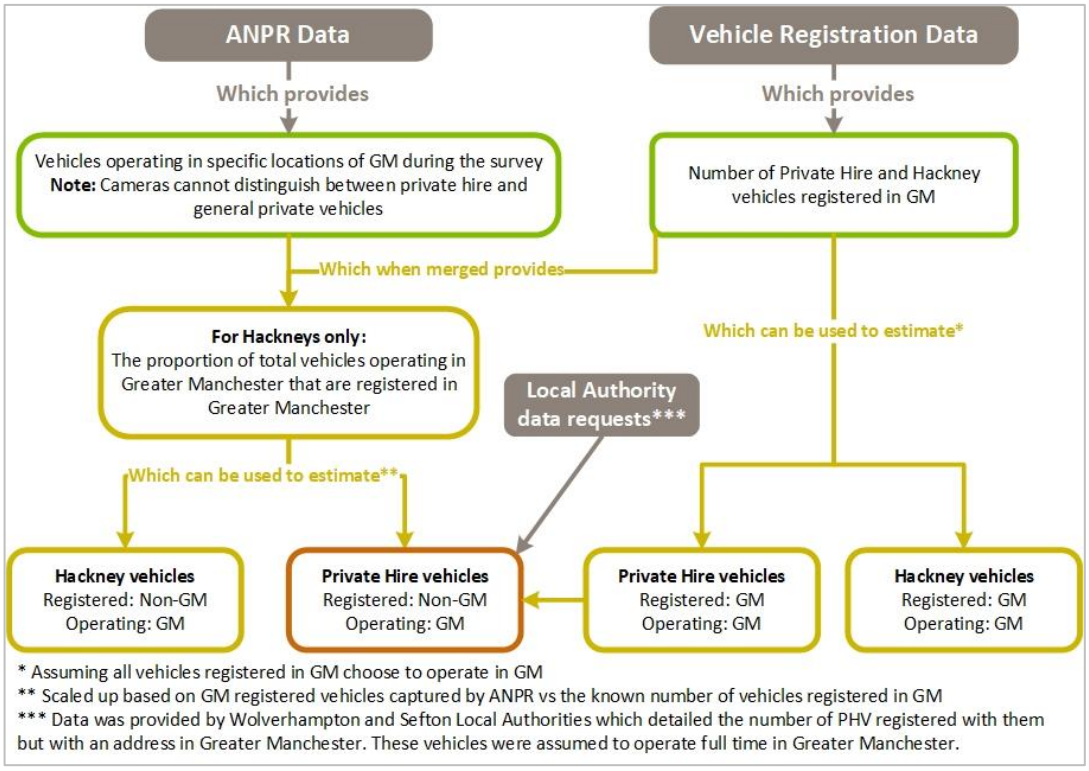


Table 3-1 Taxi input data in 2021 (Non-compliant)

	Hackney (non-compliant)	Private Hire (non-compliant)	Total (non-compliant)
GM licensed	2,100 (1,600)	12,400 (5,300)	**14,500** **(7,000)**
Licensed outside of GM	300 (200)	4,800 (2,100)	**5,100** **(2,300)**
Total	**2,400** **(1,800)**	**17,200** **(7,400)**	**19,600** **(9,300)**

3.4 Market segmentation

3.4.1 Segmenting the market allows the model to allocate vehicle owners to different decisions/responses. Generally, the more the market is segmented, the more complex it is, however too little segmentation treats the entire market as a large group who act homogeneously. The 'right' level of segmentation depends on the data available (in order to estimate the proportion of the market belonging to each segment) as well as how strongly different divisions of the market vary in their operations/types. For this model, the market was segmented into the characteristics shown in Table 3-2

3.4.2 Table 2-2 along with what source was used to determine the segmentation.

Table 3-2 Market segmentation

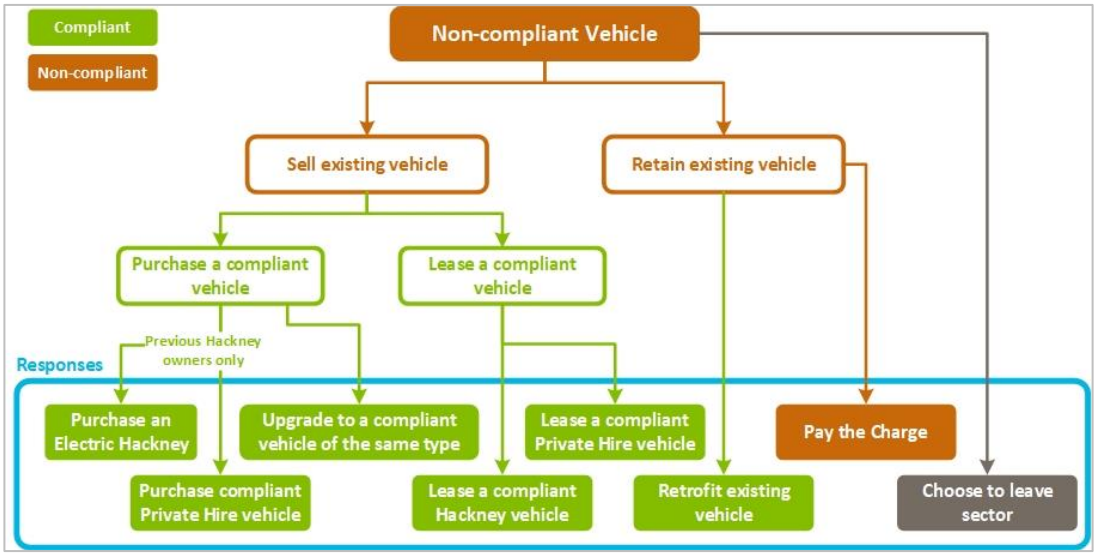
Characteristics	Segments	Source
Vehicle registration location	• Greater Manchester • Non-Greater Manchester	ANPR data and GM Licencing data (Hackneys only, Private Hire vehicles registered outside of Greater Manchester were unable to be identified[3])
Frequency (in GM)	• Occasional • Full time	ANPR data
Vehicle type	• Hackney • Private Hire	Greater Manchester Vehicle licensing fleet lists
Vehicle ownership	• Driver owner • Shared driver owner • Operator owner • Third party operator	Department for Transport (Taxi and Private Hire vehicle statistics – 2017) and Consultant opinion
Operations (usage)	• Low (part time) • Medium • High • Intensive (24/7)	Department for Transport (Taxi and Private Hire vehicle statistics – 2017)
Vehicle age	• New to 23 years old	Greater Manchester Vehicle licensing fleet lists

3.5 Define options

3.5.1 A list of possible responses to CAZ has been identified which aims to capture a high percentage of the actual responses from the market. The responses/options available to vehicle owners that have been included in the model are shown in **Figure 3-3**.

[3] To further understand the number of PHVs registed outside GM, though operating within GM, Freedom of Information requests were made to Woverhampton and Sefton, both known to have large numbers of PHVs operating within GM

Figure 3-3 Options available to vehicle owners



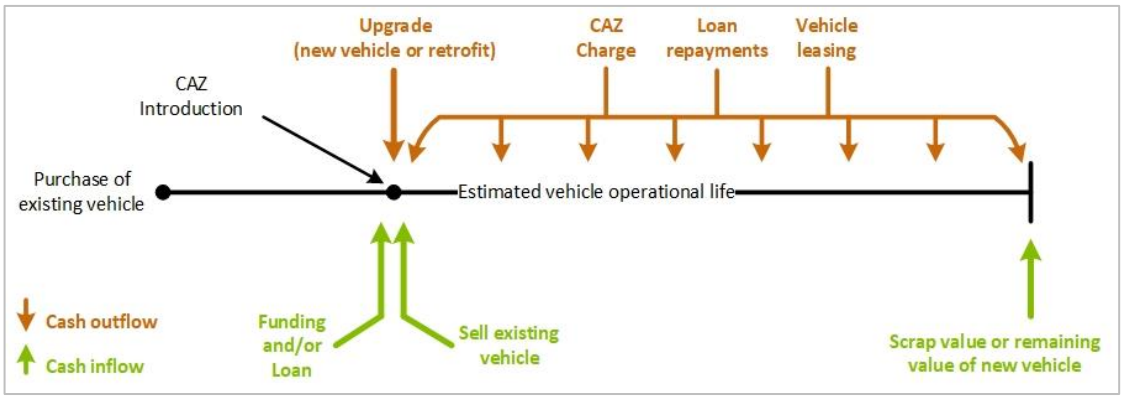
Assess options and allocate market segments

3.5.2 Each market segment was allocated to an option based on which was estimated to be best financially for the vehicle owner. The cost/value of each option was determined using a discounted cash flow model which is illustrated in **Figure 3-4**. The cash flows included in each option are shown in **Table 3-3**.

Table 3-3 Cash flows included for each option available (Hackney and Private Hire)

Option/ Response	Sell existing vehicle	Purchase new vehicle	Purchase Retrofit	Lease compliant vehicle	Funding and/or Loan	CAZ Charge	Remaining vehicle value
Do nothing (pay the charge)						✓	✓
Upgrade vehicle	✓	✓			✓		✓
Retrofit existing vehicle			✓		✓		✓
Lease a compliant vehicle	✓			✓			
Leave sector	All other options are unfeasible due to cost						

Figure 3-4 Financial analysis of options

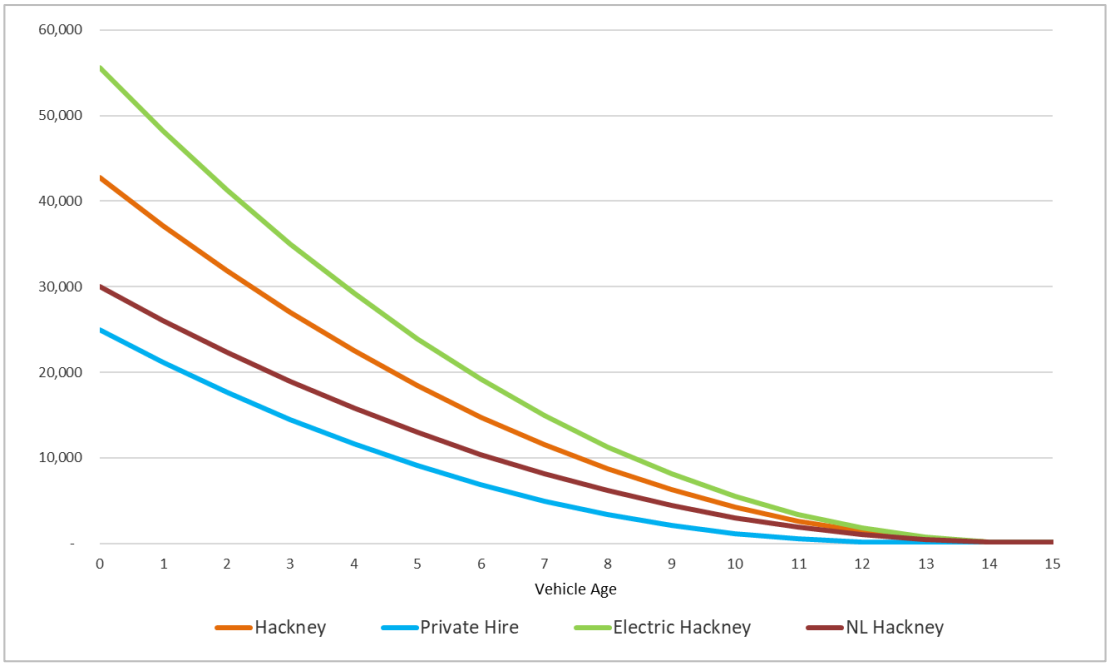


3.6 Key model assumptions

Vehicle prices and depreciation

3.6.1 The assumptions behind vehicle values have been informed by 'Note 19: Taxi and PHV Fleet Research' technical note which conducted research on vehicles cost using CabDirect. The purchase prices were then depreciated using the sum-of-years depreciation method. This produced a value curve for each vehicle which are shown in **Figure 3-5**. It is assumed that second hand vehicles are approximately four years old and the value produced by the curve has been validated using estimated costs for second hand vehicles (also discussed in Technical Note 19 Taxi and PHV Fleet Research).

Figure 3-5 Vehicle values



Preferred responses

3.6.2 For options which are estimated to be similar in terms of financial benefit to the vehicle owner (within £5,000), a set of preferences has been assumed, with the number of vehicle owners in that segment distributed between all options but weighted towards their assumed preferred options. The preferences allow for some consideration of operational cash flows such as reduced cost of fuel for electric vehicles or high wages for hackney drivers relative to private hire drivers. The preferences follow those shown in **Table 3-4**.

Table 3-4 Vehicle owner preferences

Preference	Response
1.	Upgrade vehicle
2.	Do nothing (pay the charge)
3.	Retrofit vehicle
4.	Change to lease

Prohibitions of some responses

3.6.3 To more accurately reflect the market and likely responses of different market segments, some options have been prohibited from being selected by certain market segments. Examples of these prohibitions are shown in **Table 3-5**.

Table 3-5 Prohibitions

Market segment	Prevented from choosing
All sectors	Switching to other vehicle types (i.e. Hackney to PHV)
Operator or Third-Party Owners	Change to leasing vehicles
Operator or Third-Party Owners	Purchasing second hand vehicles

Electric vehicle fuel cost savings

3.6.4 A provision for reduced cost of fuel has been included in the model based on an estimate of £25 per week (for a vehicle operating 12 hours per day, 5 days per week). The annual cost saving is then calculated for each usage category which is shown in **Table 3-6**.

Table 3-6 Fuel cost saving from electric vehicles

	Hours per day	Days per week	Weeks per year	Electric discount
Low	4	3	46	£230
Medium	8	5	46	£767
High	12	6	48	£1,440
Intensive	20	7	50	£2,917

3.7 Model opportunities

Minimum Licensing Standards

3.7.1 GM is currently considering the implementation of Common Minimum Licensing Standards (MLS) across the region. At the time of modelling the consultation option, those Standards were not confirmed and therefore have not been taken into account. However, the model includes the functionality to implement MLS alongside the GM CAP proposals to assess likely responses under these conditions, such as the possible introduction of an age limit on licensed vehicles or changes to the types of vehicles able to be licensed.

Sensitivity testing

3.7.2 In any model there are many assumptions which are informed by sources or data of varying quality and reliability. These assumptions are often set to the 'most likely' case which provides a set of outputs that can be considered the base case. There are several assumptions in this model which can be varied to assess the impact on the outputs including:

- Charging amounts and terms (which can also be varied between Hackneys and PHVs);
- Availability of funding and thus total funding pool required;
- Availability of loans and variance in loan terms;
- Second hand compliant vehicle prices;
- The cost at which vehicle owners would be happy to accept to choose their desired response;
- The cost at which vehicles owners would be forced out of the market (initial – due to liquidity issues - or long term);
- Cost of leasing vehicles; and
- Transaction costs.

Analysis of impacts on specific market segments

3.7.3 Model outputs can be disaggregated to assess particular market segments which are likely to respond in a certain way. This could indicate which market segments are financially impacted the most by the introduction of CAZ.

3.8 Model Limitations

Data relating to Private Hire Vehicles operating in Greater Manchester but registered elsewhere

3.8.1 The input data for this model is reliable for Hackney vehicles with known registration numbers in GM as well as an indication of the number of vehicles operating in GM but registered elsewhere due to the ANPR survey. Given that registration of Hackney vehicles in GM has no known benefits to registering in other nearby locations, the assumption is that all vehicles registered in GM will choose to operate within GM is reasonable.

3.8.2 Regarding PHVs, the number of vehicles registered in GM is known and these are also assumed to operate within GM. However, the ANPR cameras were unable to determine if a vehicle was a PHV (rather than a private car) and thus unable to provide an indication of vehicles operating in GM which are registered elsewhere. It is GM's understanding that the production of a national database is underway which would allow local authorities to identify PHVs registered elsewhere, but this database is not yet available. In the absence of this, it is not possible to distinguish a PHV from a private car within ANPR survey data.

3.8.3 To estimate the number of Private Hire Vehicles registered outside of GM, inquiries were made to Wolverhampton and Sefton local councils as it is known that these councils receive a disproportionate number of private hire registration applications from residents of other areas. These councils were able to provide data relating to the number of registrations which had a listed address in GM and these vehicles were assumed to be operating in GM and were therefore included in the modelling. The inquires identified approximately 1,700 Wolverhampton licensed and 1,100 Sefton licensed vehicles.

3.8.4 Wolverhampton and Sefton are not the only councils where such registration issues arise and therefore it is possible that the total number of PHVs operating in GM could be underestimated.

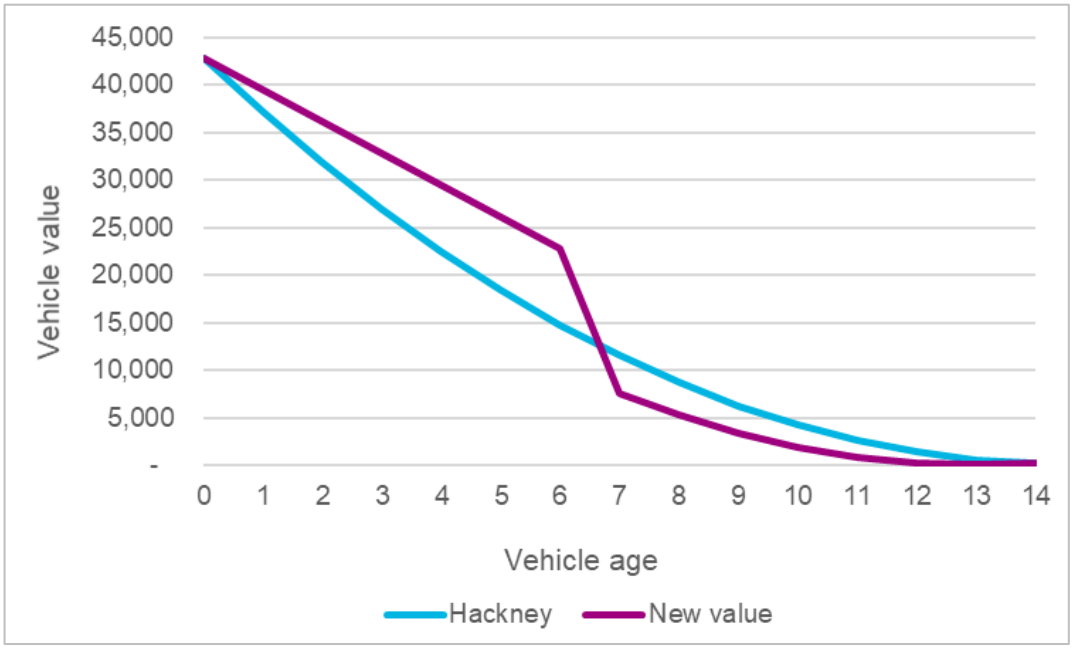
Data relating to vehicle ownership and operations

3.8.5 The model distributes vehicles to ownership types based on the vehicle's age which is then validated against survey results published in 'the Conversation' relating to fleet sizes. It is assumed that, as vehicles become older, they are more likely to be owned by drivers or under a Shared Driver owner scheme rather than by an operator or large third party. There is very limited data relating to the distribution of how intensively vehicles are used which is likely to affect the tendency of the owner to choose a particular response. Anecdotal evidence suggests that ownership patterns may vary between different districts, but this is not yet supported by quantitative evidence and so has not been taken into account.

Impacts of market distortion

3.8.6 The vehicle values shown in **Figure 3-5** represent the existing market and do not consider what the implementation of the CAZ will do to vehicle values and costs. It is likely that the value of compliant second-hand vehicles will significantly increase while the value of non-compliant vehicles (i.e. Euro V engines) will decrease. The magnitude of these changes in value will depend on local market access to the broader national market. **Figure 3-6** illustrates what could happen to the hackney vehicle market once CAZ is introduced in the scenario where the majority of vehicle owners do not have access to wider market (i.e. other UK cities implement a similar CAZ scheme meaning that supply of second-hand compliant vehicles is restricted while demand for non-compliant vehicles reduces). This figure also assumes that all vehicles less than six years old at the introduction of CAZ will be compliant while all vehicles older than six will be non-compliant which is an approximation. As shown, the price for second hand compliant vehicles could increase by as much as 30 percent or around £10,000. This would make it significantly more difficult for non-compliant vehicle owners to achieve compliancy, particularly in the absence of a retrofit option.

Figure 3-6 Indicative market distortion of Hackney vehicle values due to CAZ



Variances in operational revenue/profit between segments

3.8.7 The operational revenue or profit margins of the vehicle owners are not considered as part of the cost model. This could be a limitation as an operator that owns a fleet of vehicles and operates and earns revenue from each vehicle 24 hours per day can spread the cost of the charge more easily than an owner-driver who works shifts, which may mean the operator owner is less likely to upgrade their vehicles. Additionally, any potential reduction in revenue for operating a PHV compared to a Hackney is not considered. However, once the reduced cost of owning a PHV compared to a Hackney is included, this may skew results in favour of owning a PHV.

Vehicle market segmentation for Non-London Style Hackney and Private Hire vehicles

3.8.8 There a broad number of vehicle manufacturers and makes which can be licensed as a Hackney, depending on the local council. Licensing standards vary considerably between the local authorities in GM. Those vehicles driven under a Hackney licence that are not traditional ‘London-style’ Hackney Cabs are considered Non-London (NL) Hackney vehicles in the model. Given the range of differing vehicles and thus vehicle values in the NL Hackney and Private Hire Vehicle markets, prospective vehicle owners may be able to purchase cheaper vehicles than modelled or may prefer or be required to purchase more expensive vehicles than modelled. The vehicle which was most common to both markets was used as the benchmark in the model.

Electric vehicle infrastructure

3.8.9 The uptake of electric vehicles has only been considered in the model from a cost perspective. What is not considered is the level of infrastructure to be provided and if it will be considered adequate for prospective electric vehicle owners. The assumption in the model is that a lack of infrastructure will not be a barrier to electric vehicle uptake, although in practice this is a significant concern and limiting factor, and uptake of electric taxis is only likely if supporting infrastructure is put in place. This also means that the 'CAZ Only' scenario is likely to overstate the upgrade response. However, at present uptake of electric taxis is very low in GM and the modelled response does not reflect concerns within the trade about the practicality of electric taxis, especially given the lack of charging infrastructure.

3.8.10 The model also does not take into account the fact that the high cost of upgrade to an electric taxi means that in order to realise the operational cost savings, drivers must have access to equity/savings or affordable credit. Qualitative research evidence suggests that in reality this is a major barrier to upgrade, which would mean that the 'CAZ with funds' behavioural responses could be considered more realistic than the 'CAZ only' responses.

3.9 Model Outputs

The model has produced a set of responses for a base case scenario (no funding) as well as a funding scenario for CAZ implementation years of 2021 and 2023. These results form the basis of the response input to the DST after consideration has been given to exemptions for wheelchair accessible vehicles (WAVs).

3.9.1 **Table 3-7**Error! Reference source not found. below shows the behavioural responses for the CAZ-only result.

Table 3-7 CAZ-only Updated Behavioural Responses - Hackney/PHV

Hackney Carriage			
Modelled Response	2021	2023	2025
Pay Charge	*Not Applicable (Wheelchair accessible vehicles exempt until 2023)* [4]	26.4%	32.8%
Change Mode		0.0%	0.0%
Cancel Trip		0.0%	0.0%
Upgrade: Purchase - Upgrade		38.3%	12.8%
Upgrade: Purchase - Retrofit		6.1%	4.0%
Upgrade: Purchase Electric Hackney		22.5%	21.3%
Upgrade: Change to Lease (Hackney)		5.8%	15.8%
Upgrade: Change to Lease (Elec Hackney)		0.8%	13.4%
Total Upgrade		73.6%	67.2%
PHV			
Modelled Response	2021	2023	2025
Pay Charge	12.1%	16.2%	18.9%
Change Mode	0.0%	0.0%	0.0%
Cancel Trip	4.3%	0.5%	0.0%
Upgrade: Purchase - Upgrade	30.7%	25.3%	18.9%
Upgrade: Purchase Electric	38.9%	39.9%	40.9%
Upgrade: Change to Lease (Elec)	10.1%	7.2%	5.7%
Upgrade: Change to Lease (Private Hire)	4.0%	10.8%	15.6%
Total Upgrade	83.6%	83.3%	81.1%

Source: Taxi Cost Model

[4] Note: within the modelling all hackneys are assumed to be Wheelchair Accessible Vehicles (WAV) and so are assumed to be exempt until 2023. In practice, around 300 Hackney cabs are not WAV and therefore would be required to pay the charge (mostly in the outer districts of GM) and conversely, around 100 PHVs are WAVs and would be exempt, but are assumed here to be charged.

3.9.2 For the 2021 ‘CAZ plus funds’ scenario, the funding available for upgrades is assumed to be as follows:

- Zero Emission WAV Hackney - £10,000;
- Retrofit to LPG (London-style Hackney cabs only) - £5,000;
- Compliant non-WAV Hackney and PHV – £2,000; and
- Zero Emission non-WAV Hackney and PHV - £4,000.

3.9.3 **Table 3-8** below provides the findings from the ‘CAZ plus funds’ model run.

Table 3-8 CAZ + Updated Behavioural Responses - Hackneys/PHV

Hackney Cab			
Modelled Response	2021	2023	2025
Pay Charge	*Not Applicable (Wheelchair accessible vehicles exempt until 2023)*	25.7%	27.6%
Change Mode		0.0%	0.0%
Cancel Trip		0.0%	0.0%
Purchase - Upgrade		26.2%	11.7%
Purchase - Retrofit		13.5%	7.4%
Purchase Electric Hackney		30.1%	30.0%
Change to Lease (Hackney)		4.4%	14.9%
Change to Lease (Elec Hackney)		0.2%	8.3%
Total Upgrade		74.3%	72.4%
PHV			
Modelled Response	2021	2023	2025
Pay Charge	11.4%	15.8%	17.7%
Change Mode	0.0%	0.0%	0.0%
Cancel Trip	4.3%	0.4%	0.0%
Purchase - Upgrade	34.6%	30.3%	31.2%
Purchase Electric	36.7%	36.8%	33%
Change to Lease (Elec)	9.6%	5.9%	3.1%
Change to Lease (Private Hire)	3.4%	10.8%	15%
Total Upgrade	84.3%	83.8%	82.3%

Source: Taxi Cost Model

4 Demand Sifting Tool

4.1 Overview of the DST

4.1.1 The Demand Sifting Tool (DST) has been developed as part of the GM CAP to test various options, with the aim of finding the key measures that could tackle NO_2 concentrations and improve air quality.

4.1.2 Initially the tool was developed using Microsoft Excel, however, as additional responses were incorporated and a more detailed sector system adopted, run times became too time consuming. As a result, the tool was enhanced for the Do Something (DS) process which now utilises SQL Server to run several calculations in a database, vastly reducing the run time.

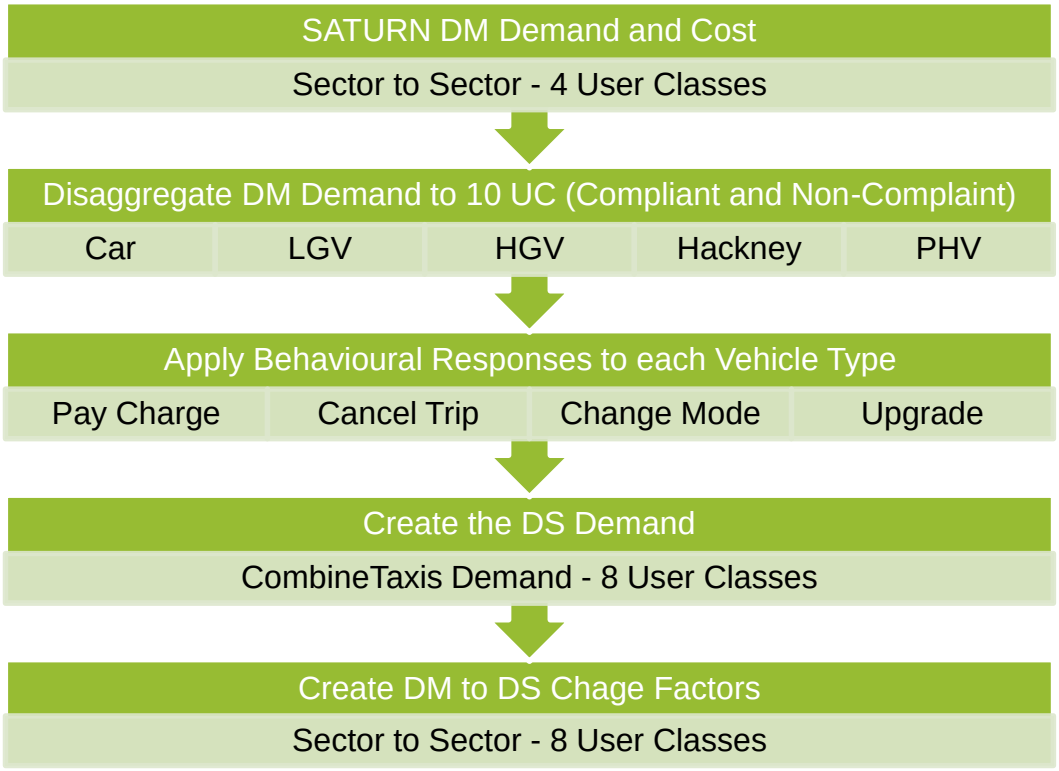
4.1.3 An operating manual for the DST is provided in **Appendix D** of the T4 note.

4.2 DST Process

4.2.1 The DST processes the Do Minimum (DM) demand matrices that are exported from the SATURN traffic model, disaggregates it into 10 user classes (UC), applies various behavioural responses to the demand based on the charges imposed on each vehicle type, and then creates the Do Something (DS) demand change factors. The change factors are then applied to the DM demand in order to create the DS demand.

4.2.2 The DST process is illustrated in **Figure 4-1** below:

Figure 4-1 DST Process



4.2.3 The DST can be used to:

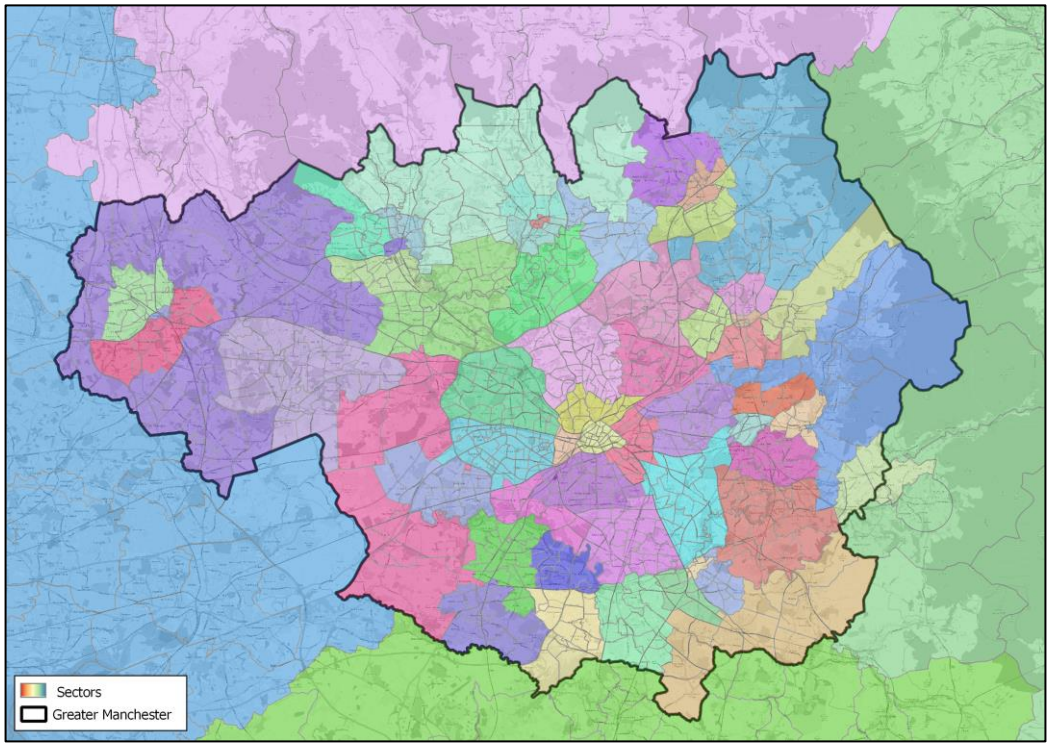
- Analyse the impact of various charges imposed on each user class;
- Help improve options and key measures by showing their impacts; and
- Assess the impacts of change mode behavioural responses.

4.3 Key Model Inputs

Do Minimum Demand (Sectored)

4.3.1 Prior to incorporating the demand from the SATURN model, a sectoring process is applied to convert the SATURN model's 1,034 zones into a 62 sector system. The sectors are largely focused on urban and suburban centres with a higher level of aggregation in rural and Non-GM areas. A summary of the Sector System is provided in **Figure 4-2**.

Figure 4-2 Sector System



4.3.2 To add more granularity (given the aggregated nature of the sector system) every zone to zone pair has also been assigned to a distance band in line with the National Travel Survey (NTS).

4.3.3 For the Do Minimum DST, aggregated demand for four user classes is provided, from the SATURN model, covering:

- Cars;
- LGV;
- HGVs; and
- Taxis (Hackney & PHV combined).

Behavioural Responses

4.3.4 The behavioural responses discussed in the earlier chapters of this report are a key input to the DST. These responses have been estimated using the cost models and capture the following responses:

- Pay Charge;
- Change Mode (applies to LGVs upsizing to HGV or downsizing to Car, and HGVs downsizing to LGVs);
- Cancel Trip or Leave Sector; and
- Upgrade Vehicle.

4.4 Model Calculations

Demand Segmentation

4.4.1 The demand from the highway model, following input to the DST is segmented into several user classes. These are shown in **Table 4-1**.

Table 4-1 Segmentation of Model Demand

Vehicle Class		Compliance	Parking Type
Car		Compliant	On Street – Paid
			Car Park – Paid
			Park and Ride
			Free/Residential
		Non-Compliant	On Street – Paid
			Car Park – Paid
			Park and Ride
			Free/Residential
LGV		Compliant	N/A
		Non-Compliant	N/A
HGV		Compliant	N/A
		Non-Compliant	N/A
Taxi	Hackney	Compliant	N/A
		Non-Compliant	N/A
	Private Hire Vehicle	Compliant	N/A
		Non-Compliant	N/A

Application of Behavioural Responses

4.4.2 The changes in demand associated with the behavioural responses are applied within the cost model to determine the changes from non-compliant to compliant from the upgrade responses output from the cost models. Any change mode responses are also captured.

Reflecting Change Mode Responses

4.4.3 The cost models have identified some change mode responses. As a result, additional functionality was developed within the DST to allow the flow of trips into different modes. In particular, the functionality included:

- HGVs downsizing to LGVs;
- LGVs upsizing to HGV;
- LGVs downsizing to Cars;
- Hackneys switching to PHVs; and
- PHVs switching to Hackneys.

Applying Behavioural Responses for Taxis/PHVs

4.4.4 The SATURN model does not model Hackneys and PHVs separately, as these are merged together into a single taxi mode. The behavioural responses to the CAP for Hackneys and PHVs are expected to be quite different, with separate responses generated as an output from the Taxi Cost Model. Therefore, to reflect these differing responses, additional functionality was applied within the DST to assess the behavioural responses for each sub mode. This included:

- Disaggregation of the taxi mode into Hackneys and PHVs, based on data from the GM taxi fleet list (this increased the number of matrices from 8 to 10 for each time period);
- Behavioural responses are applied separately for Hackneys and PHVs; and
- The output changes in demand for Hackneys and PHVs are calculated by the DST, with output trip volumes merged back into an overall taxi matrix, with a taxi change matrices outputted which has incorporated the detailed behavioural changes.

4.5 DST Model Outputs

Demand Outputs

4.5.1 The key output of the DST is the changes in vehicle demand for each of the user classes, in particular focusing on changes in compliant and non-compliant vehicle volumes.

4.5.2 The DST has been developed to produce change factors for each sector to sector movement (62 sectors) by distance band and modelled user class in each time period.

4.5.3 These factors are then applied to all zone-to-zone movements in the SATURN matrix with the same sector to sector Origin/Destination distance band and user class to give updated matrices. Given the size of the GM SATURN zoning system this has been carried out in an external database and then matrices have been re-created using the 'MX' function in SATURN.

Other DST Outputs

4.5.4 Outputs from the DST have also been used to inform the financial case where trips in the morning peak (AM), inter-peak (IP), and evening peak (PM) have been converted into vehicles per day to estimate the number of vehicles likely to pay the charge and therefore the revenue generated in the following process:

- Annual Average Daily Trip (AADT) factors have been applied to generate daily trip totals; and
- Trip frequency assumptions (developed at OBC) have been applied to estimate expected vehicle volumes.

4.6 Impact on Compliance

4.6.1 The DST was run with the behavioural responses to understand the impact on compliant vehicles figures for HGV, LGV, and Taxi.

HGV DST Results

4.6.2 The changes in HGV trips for the various years are shown in **Table 4-2**, **Table 4-3**, and

4.6.3 **Table** 4-4. The inclusion of the HGV fund response does have a small impact on the level of compliance. It is therefore important to note the following:

- A significant upgrade response to the CAZ is seen in all forecast years, even with the refined £60 CAZ charge;
- The incremental impact of the funds is small, this is because the 'CAZ Only' scenario predicts a significant upgrade response;
- The impact of the funds is limited to 2021;
- Behavioural response for HGVs in the cost response model reflect a separate response for a range of different commodity types which are then amalgamated to create an overall HGV behavioural response for the GM-CAP;
- The cost response model also allows the ability to vary the allocation of funds by weight category; and
- The response includes a 'change mode' response, which allows the functionality for a HGV trip to switch to an LGV trip (though noting the refined behavioural responses predict a negligible switch to mode response).

Table 4-2 HGV Fund Impact on Compliance – 2021

Period	Scenario	Do-Minimum	CAZ Only	CAZ plus funds
AM Peak	Compliant	22,800	28,400	28,400
	Non-Compliant	9,200	3,600	3,600
	Total	32,000	32,000	32,000
Inter Peak	Compliant	24,800	30,900	30,900
	Non-Compliant	10,100	4,000	4,000
	Total	34,900	34,900	34,900
PM Peak	Compliant	12,000	14,700	14,700
	Non-Compliant	4,800	2,100	2,100
	Total	16,800	16,800	16,800

Source: DST – Trip volumes by compliance type

Table 4-3 HGV Fund Impact on Compliance - 2023

Period	Scenario	Do-Minimum	CAZ Only	CAZ plus funds
AM Peak	Compliant	26,700	30,100	30,100
	Non-Compliant	5,800	2,400	2,400
	Total	32,500	32,500	32,500
Inter Peak	Compliant	29,000	32,800	32,800
	Non-Compliant	6,400	2,600	2,600
	Total	35,400	35,400	35,400
PM Peak	Compliant	14,000	15,700	15,700
	Non-Compliant	3,100	1,400	1,400
	Total	17,100	17,100	17,100

Source: DST – Trip volumes by compliance type

Table 4-4 HGV Fund Impact on Compliance - 2025

	Scenario	Do-Minimum	CAZ Only	CAZ plus funds
AM Peak	Compliant	30,000	31,800	31,800
	Non-Compliant	2,900	1,100	1,100
	Total	32,900	32,900	32,900
Inter Peak	Compliant	32,700	34,600	34,600
	Non-Compliant	3,100	1,200	1,200
	Total	35,800	35,800	35,800
PM Peak	Compliant	15,800	16,600	16,600
	Non-Compliant	1,500	700	700
	Total	17,300	17,300	17,300

Source: DST – Trip volumes by compliance type

LGV DST Results

4.6.4 The changes in LGV trips for the various years are shown in **Table 4-5** and **Table 4-6**. The LGV response including the CAZ plus funds shows an increase in compliant vehicles when compared to the CAZ only. It is therefore important to note the following:

- 2021 impacts are excluded as LGVs are exempt from charges until 2023;
- Overall, there is a small reduction in the number of LGVs from the Do Minimum (2023 only) - this is due to the change mode functionality;
- The funds have a notable impact on compliance, further reducing the number of non-compliant vehicles;
- The response included a ‘change mode’ response of 3.4% in 2023 (i.e. change to a car or HGV). The DST was recently updated to include this functionality, and as a result of this response a small change to the car and HGV matrices were considered; and
- The LGV upgrade response to an electric vehicle is currently merged within the wider response to upgrade to a compliant vehicle. As upgrade to an electric vehicle will have a much greater impact on air quality than simply upgrading to a compliant vehicle, this will be an aspect of further investigation to support the FBC submission and, if considered appropriate, the results will be captured in the EMIGMA model, post highway assignment model.

Table 4-5 LGV Impact on Compliance (£10 charge) - 2023

	Scenario	Do Minimum	CAZ Only	CAZ plus funds
AM Peak	Compliant	35,100	45,200	48,200
	Non-Compliant	16,600	5,700	2,900
	Total	51,700	50,900	51,100
Inter Peak	Compliant	34,300	44,100	47,000
	Non-Compliant	16,200	5,700	3,000
	Total	50,500	49,800	50,000
PM Peak	Compliant	29,700	38,200	40,700
	Non-Compliant	14,100	5,000	2,600
	Total	43,800	43,200	43,300

Source: DST – Trip volumes by compliance type

Table 4-6 LGV Impact on Compliance (£10 charge) - 2025

	Scenario	Do Minimum	CAZ Only	CAZ plus funds
AM Peak	Compliant	42,700	50,500	51,900
	Non-Compliant	11,400	3,600	2,200
	Total	54,100	54,100	54,100
Inter Peak	Compliant	41,600	49,200	50,500
	Non-Compliant	11,100	3,500	2,200
	Total	52,700	52,700	52,700
PM Peak	Compliant	36,100	42,700	43,800
	Non-Compliant	9,700	3,100	2,000
	Total	45,800	45,800	45,800

Source: DST – Trip volumes by compliance type

4.6.5 These runs of the DST have shown a similar, though slightly higher volume of non-compliant values to the OBC version, when including the impacts of the funds (2023).

Taxi DST Results

4.6.6 The changes in taxi trips for the various years are shown in **Table 4-7**, **Table 4-8** and **Table 4-9**.

4.6.7 The inclusion of CAZ plus funds shows compliance improvements across all three years. It should be noted that results are considered worst case, as it is possible that the imposition of Common Minimum Licensing Standards for taxis across GM (a potential policy currently under review) would further reduce the number of non-compliant vehicles, by ensuring the GM registered fleet align with particular standards such as age limits or emissions standards.

4.6.8 Hackneys and PHVs have been combined to provide a total compliant figure. The tables below show that there are very minor increases in the 'CAZ plus funds' scenario compliant rates when compared to the 'CAZ-only' scenario across all years.

Table 4-7 Taxi Impact on Compliance – 2021

	Scenario	Do Minimum	CAZ-only	CAZ plus funds
AM Peak	Compliant	14,800	21,800	21,800
	Non-Compliant	10,000	3,000	3,000
	Total	24,800	24,800	24,800
Inter Peak	Compliant	12,200	18,000	18,000
	Non-Compliant	8,300	2,500	2,500
	Total	20,500	20,500	20,500
PM Peak	Compliant	15,100	22,300	22,300
	Non-Compliant	10,300	3,100	3,100
	Total	25,400	25,400	25,400

Source: DST – Trip volumes by compliance type

Table 4-8 Taxi Impact on Compliance – 2023

	Scenario	Do Minimum	CAZ-only	CAZ plus funds
AM Peak	Compliant	19,800	24,100	24,100
	Non-Compliant	5,300	1,000	1,000
	Total	25,100	25,100	25,100
Inter Peak	Compliant	16,400	20,000	20,000
	Non-Compliant	4,400	800	800
	Total	20,800	20,800	20,800
PM Peak	Compliant	20,300	24,600	24,600
	Non-Compliant	5,300	1,000	1,000
	Total	25,600	25,600	25,600

Source: DST – Trip volumes by compliance type

Table 4-9 Taxi Impact on Compliance – 2025

	Scenario	Do Minimum	CAZ-only	CAZ plus funds
AM Peak	Compliant	23,400	25,000	25,000
	Non-Compliant	2,100	500	500
	Total	25,500	25,500	25,500
Inter Peak	Compliant	19,400	20,700	20,700
	Non-Compliant	1,700	400	400
	Total	21,100	21,100	21,100
PM Peak	Compliant	23,900	25,500	25,500
	Non-Compliant	2,100	500	500
	Total	26,000	26,000	26,000

Source: DST – Trip volumes by compliance type