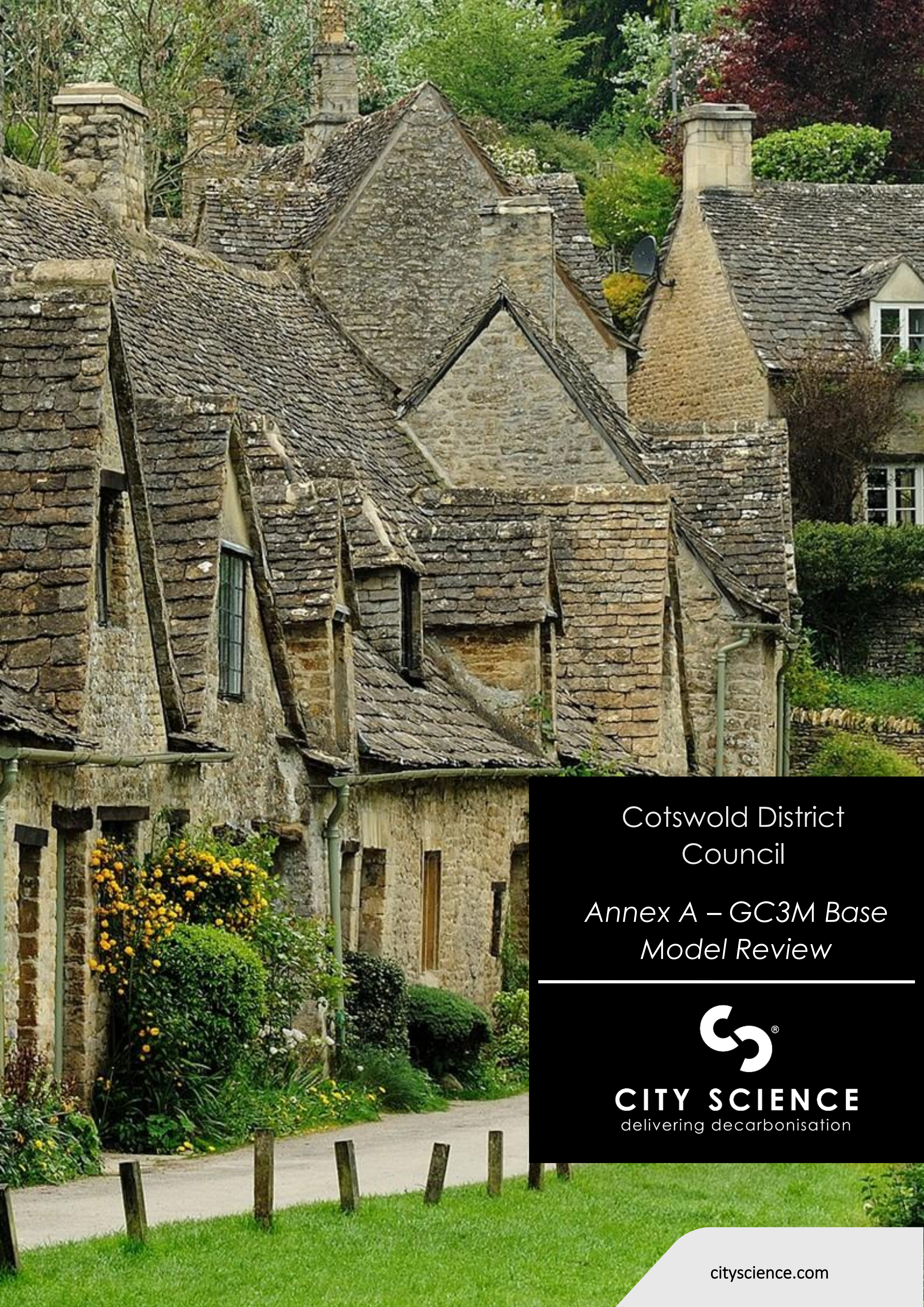

Cotswold District Council

Annex A – GC3M Base Model Review

CITY SCIENCE

delivering decarbonisation

Document details

Date issued: 09/07/2026

Document status: Final

Version number: 1.1

Document history

Version	Date issued	Description
0.1	05/09/2025	First Draft
1.0	12/09/2025	Updated following CDC Feedback
1.1	09/07/2026	Updated for the STA

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Contents

1 Introduction

1.1 Overview

City Science has been commissioned by Cotswold District Council (CDC) to support the development of the Regulation 19 transport evidence base for the Cotswold Local Plan. For this work, the Gloucestershire Countywide Multi-Modal Model (GC3M), owned by Gloucestershire County Council, has been identified as the most appropriate tool given its geographic coverage. The GC3M will support the identification of the preferred spatial option, assess the impacts of Local Plan land use on the transport network, and test potential transport interventions to inform the strategic transport assessment. Figure 1:1 illustrates the extent of the GC3M and highlights the Cotswold District area within its boundary.

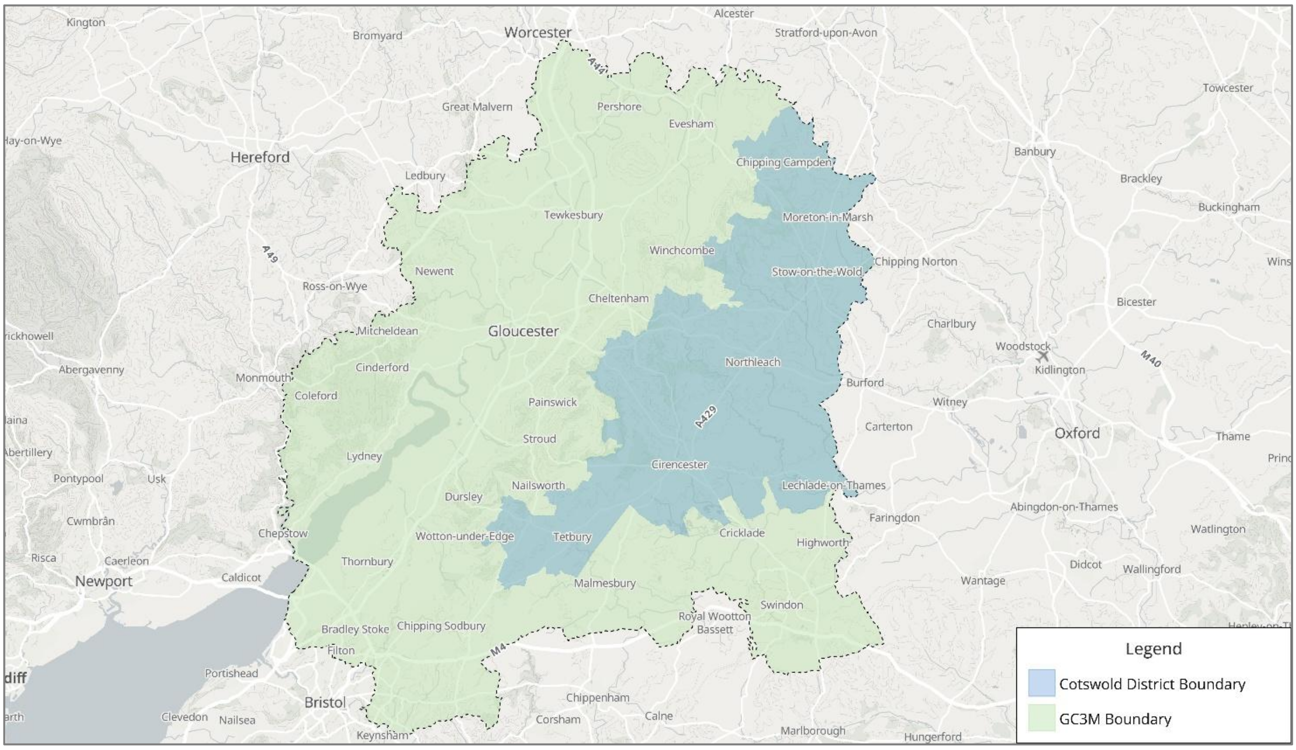

Figure 1:1: Extent of the GC3M and Cotswold District Boundary

1.2 Note Purpose

The purpose of this note is to present findings from our review of the GC3M 2019 base model, with the objective of assessing its suitability for supporting the Cotswold Local Plan strategic transport assessment, identifying areas requiring enhancement, and ensuring alignment with best practice and DfT Transport Appraisal Guidance (TAG).The GC3M is a strategic model covering both highway, public transport (bus and rail) and active modes, it was developed to test land use strategies and transport schemes. Its base year is 2019, which has been calibrated and validated against observed data. It has forecast years for 2031, 2041, 2046, and 2061. There are no plans to rebase the model.

Our review examines the GC3M's available data, network representation, model calibration and validation within the Cotswold area, and the various components of the model, namely the highway assignment model, the public transport model, and the Variable Demand Model (VDM). Particular attention is given to flow and journey time validation around major sites being considered in the local plan, as well as the adequacy of connectivity, network detail, and zone structure in representing these sites.

1.3 Summary

Overall, the review finds that the GC3M performs to a generally good standard, meeting most TAG calibration and validation criteria. Nevertheless, observations are made of area of model weakness including potential areas for improvement if required, given its use in supporting the transport evidence base for future decision-making.

2 Data Review

2.1 Overview

The most recent GC3M development, which has a 2019 base year, did not involve new data collection; existing sources were used and adjusted to represent 2019 conditions. For the Cotswold area, existing data including rail data, bus data, traffic counts, screenlines and journey time routes have been reviewed and are summarised below.

2.2 Rail Data

Due to the absence of new boarding and alighting rail passenger surveys, the availability of independent rail passenger count data is limited. Validation of modelled rail passenger flows from the GC3M public transport assignment was undertaken at an aggregated annual level using the Office of Rail and Road annual station usage statistics. While this provides a high-level check, the lack of finer granular validation data limits confidence in local model performance.

It is noted that at the time of the model build, it was not possible to undertake on-site surveys due to COVID shutdowns. However, it is also important to note although model validation was carried out using the annual Office of Road and Rail statistics, granular MOIRA data at the hourly level was used for calibration. It is considered that MOIRA is a robust source for station entries and exits, and from experience it is typically closely aligned with well-conducted survey data.

2.3 Bus Data

Similarly, no new bus passenger surveys were conducted. Validation of modelled bus passenger flows from the public transport assignment relies on aggregated annual data from the Department for Transport bus statistics. This approach provides only a broad assessment of bus passenger demand and does not support route-level validation.

Similar to the rail data approach, it is noted that, electronic ticket machine (ETM) data was collected from bus operators. This data is highly granular, recorded at the fare stage level with time stamps, and serves as a robust source for boarding information. However, ETM data lacks direct alighting information. To address this, alighting points were inferred from single and return tickets, where accurate alighting data is available - this accounts for approximately 20% of total ticket sales. These partial tickets were then expanded to represent total ticket sales, as outlined in Section 7.4.3 of the Model Development and Validation Report (MDVR).

2.4 Traffic Counts

Traffic counts within the GC3M base model provide a good representation of travel patterns across the Cotswold District, as they are well distributed across the network rather than concentrated in a single area. The coverage ensures that both strategic and local routes are captured, improving the robustness of the model calibration. Cirencester is well covered, with a cluster of counts located on its key entry and exit roads, ensuring that traffic movements into and out of the town are accurately reflected. Additional counts are also spread across important corridors such as the A429 and towards Stow-on-the-Wold, Northleach, and Moreton-in-Marsh. Figure 2:1 illustrates the existing traffic counts in the Cotswold district.

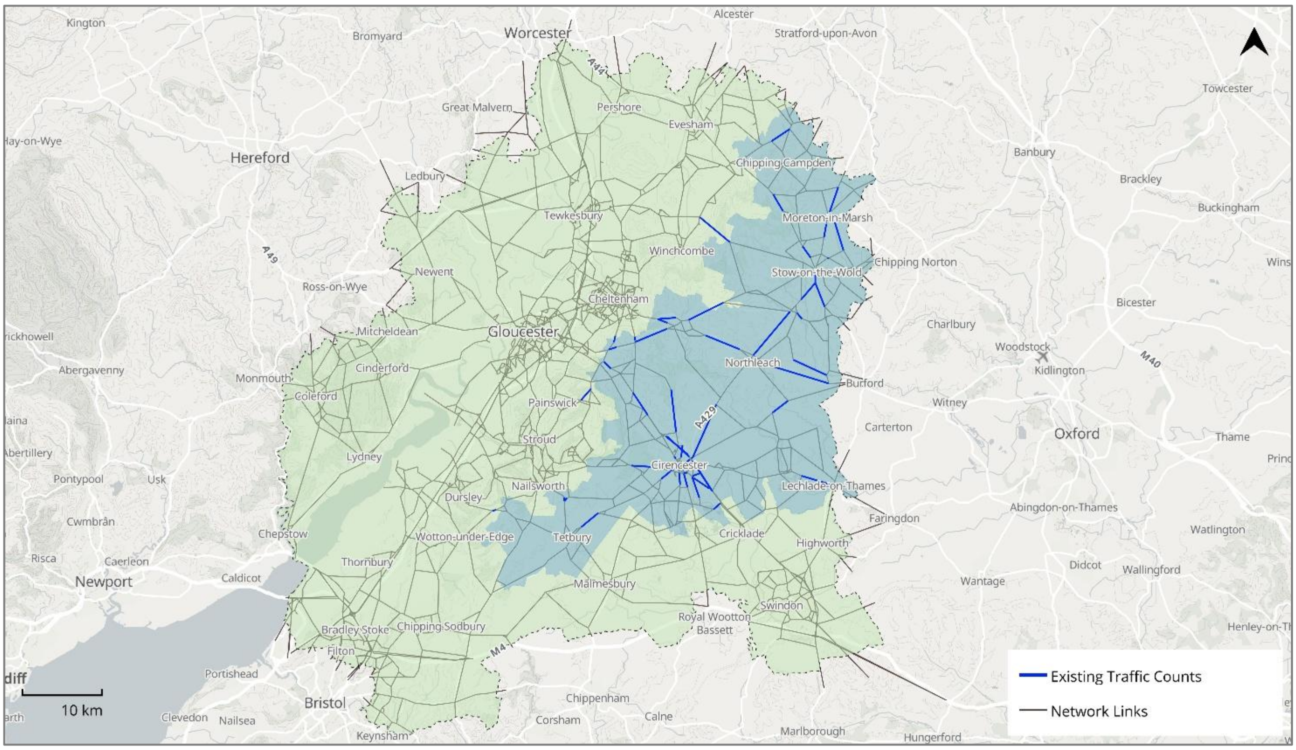

Figure 2:1. Existing Traffic Counts in the Cotswold District

2.5 Screenlines

The 2019 base GC3M includes a set of cordons and screenlines that provide a good framework for validating traffic movements across the Cotswold District. A cordon is established around Cirencester, capturing entry and exit flows to this key urban area. In addition, wider screenlines are positioned to the east of the district (covering Stow-on-the-Wold and Moreton-in-Marsh), south of Nailsworth, and to the west of the Cotswolds. These locations are effective in capturing both strategic through-traffic and local trips, providing a good spread across the district's network. Two screenlines (west of Cotswold and south of Nailsworth) were used for calibration, while one screenline (east of Cotswold) and the Cirencester cordon were used for model validation. Together, they give confidence that traffic flows are being robustly checked in both urban and rural contexts. Figure 2:2 shows the GC3M screenlines and cordons in the Cotswold district.

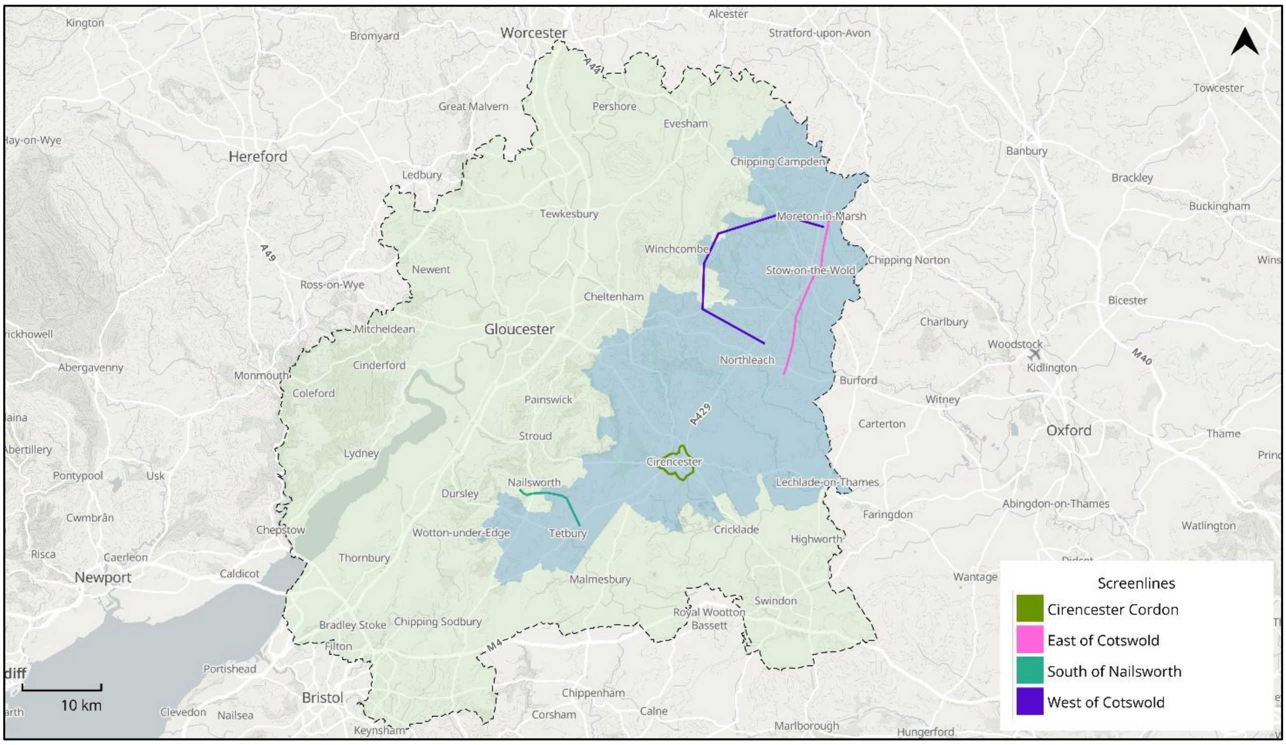

Figure 2:2 GC3M Screenlines and Cordons in the Cotswold District

2.6 Journey Time Routes

In total, six two-directional journey time (JT) routes have been defined in the base model (refer to Figure 2:3). These cover the major corridors within the Cotswold District, including the A40, A4135, A429, and A435, as well as key parts of the Strategic Road Network (SRN), namely the A417 and A419. Collectively, these routes provide good coverage of the network, allowing journey time validation to be undertaken across both local and strategic movements.

However, it is recommended that two additional journey time routes be introduced to strengthen the coverage of the network, particularly in the north of the Cotswold District. These would include:

- A44 – forming an important east–west corridor through Moreton-in-Marsh.
- A424 – serving as a key corridor through Stow-on-the-Wold.

Figure 2:4 shows the location of the proposed journey time routes.

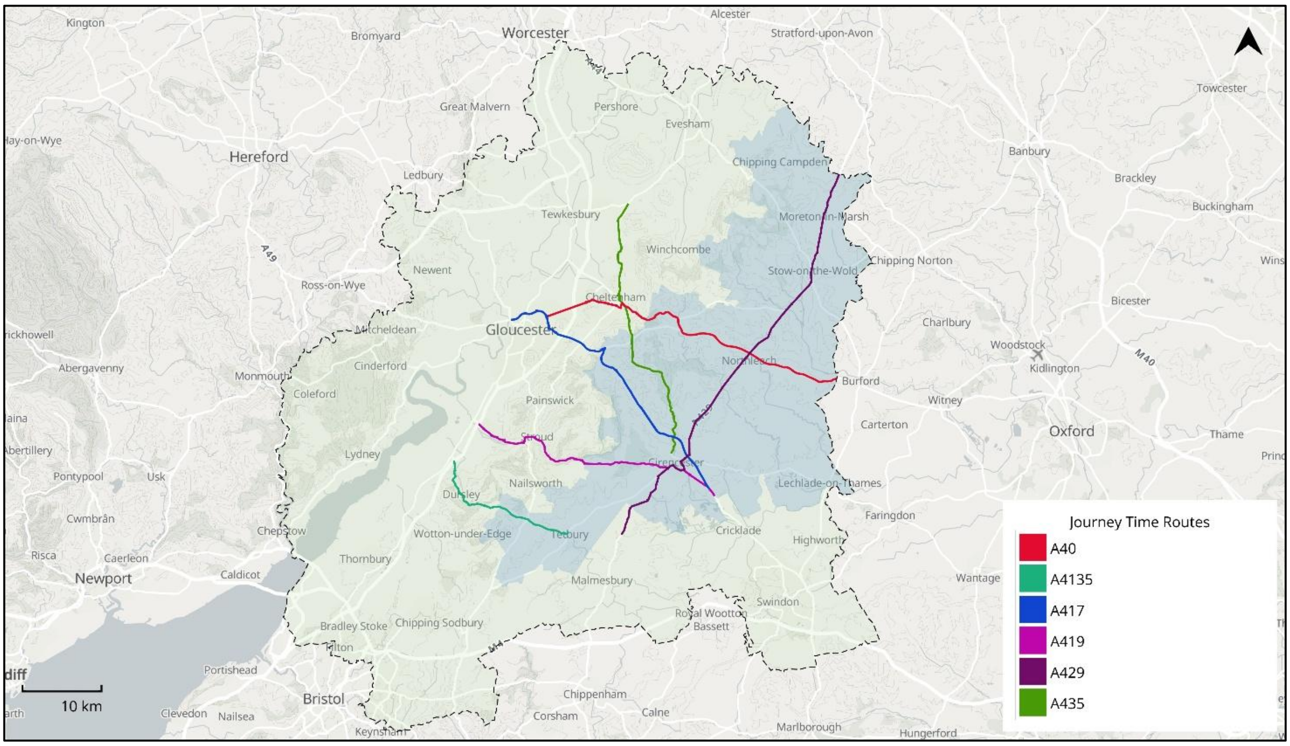

Figure 2:3 GC3M Journey Time Routes in the Cotswold District (from 2019)

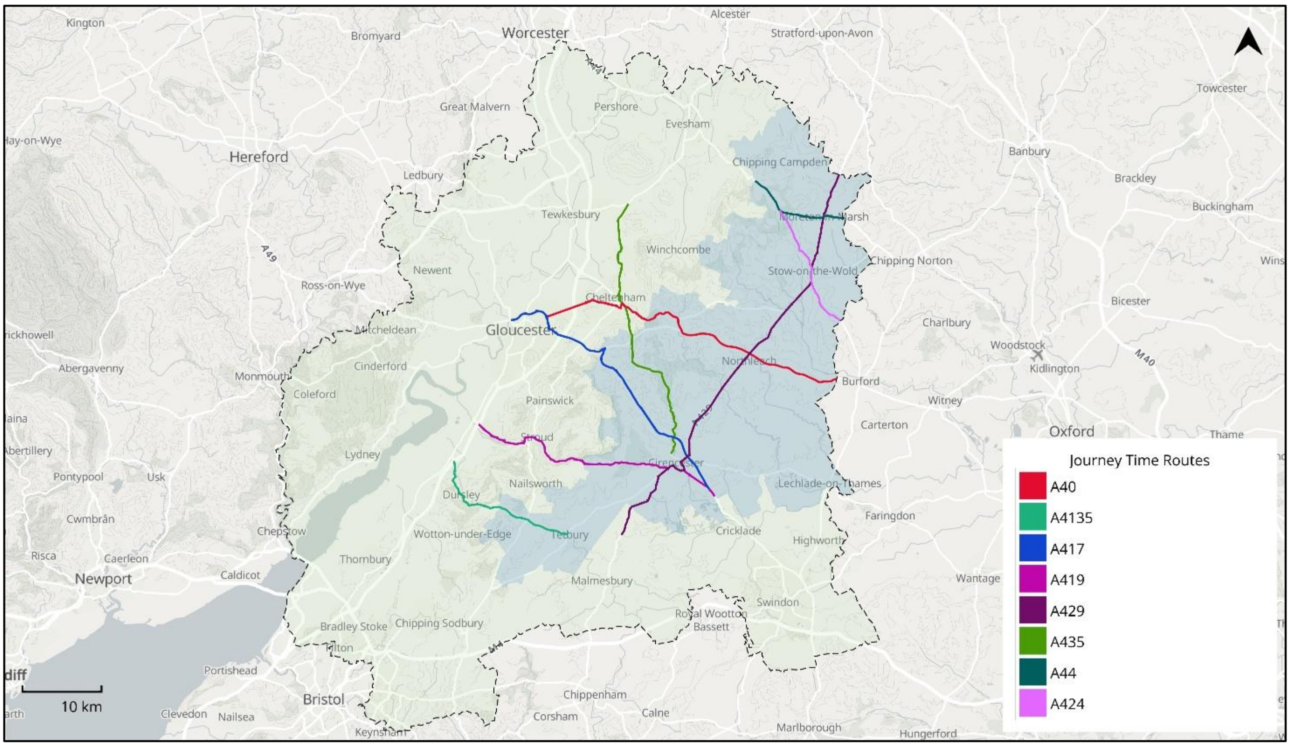

Figure 2:4 Proposed Journey Time Routes (including the two additional) for 2024

3 Network Review

3.1 Node & Link Structure

Review of the GC3M SATURN network representation indicates that dummy nodes are primarily located outside of the simulation external areas of the model for example around the Bristol area. While these are often used to simplify coding or support assignment stability, their excessive use can reduce the accuracy of the network representation and should be reviewed. This is not considered a concern at this stage of the model review. Furthermore, the locations of large developments have been provided, and none are in proximity to dummy nodes

3.2 Signal Coding

There are 18 signalised junctions with observed data available. The remainder are coded using template or default settings. Where possible, observed data should be incorporated to better reflect actual signal timings and delay patterns. In addition to this, pedestrian phases are missing for some modelled junctions. As part of the review, we identified three signalised junctions where the staging, timings, or saturation flows are incorrect, as illustrated in the figure below.

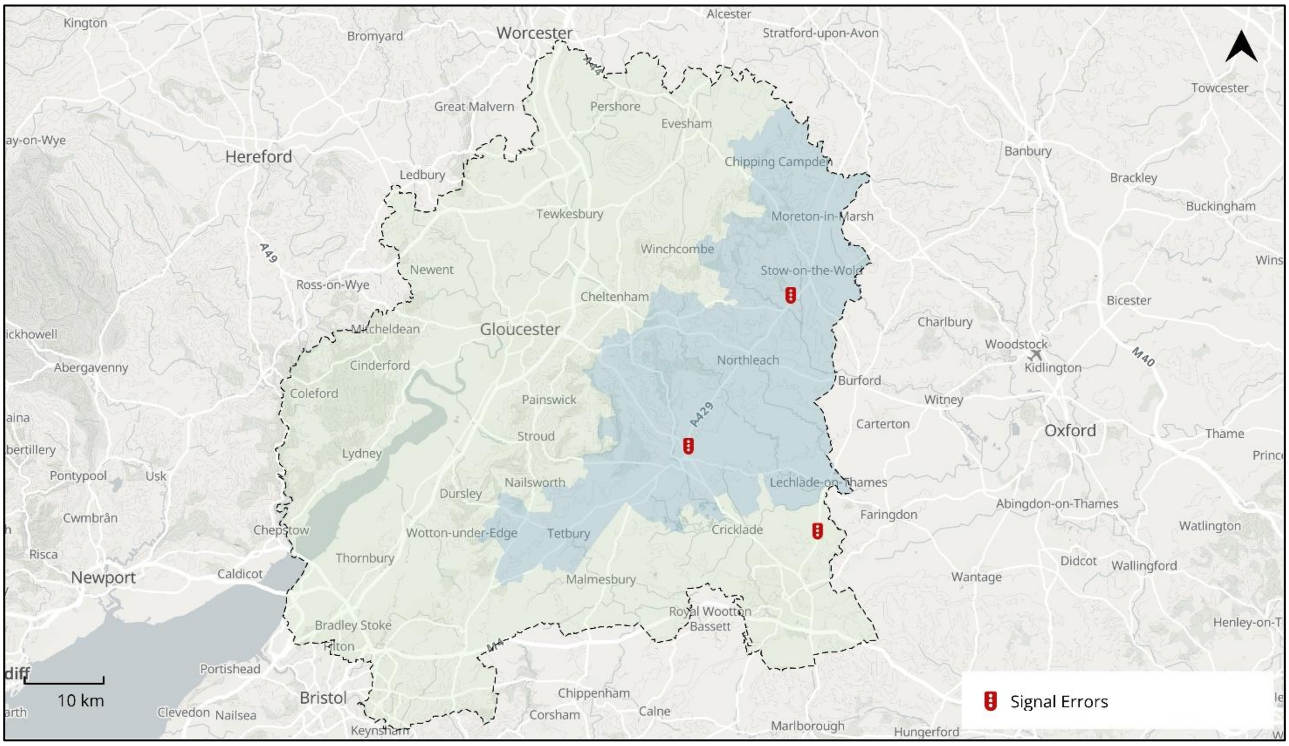

Figure 3:1 Signalised Junctions with Incorrect Inputs

3.3 Buffer Area Speeds

The fixed speeds applied in the buffer area remain unchanged from the 2015 model. Given network changes and evolving travel behaviour, it is recommended that buffer area speeds are reviewed and, where necessary, updated to ensure appropriate route choice behaviour compared with the simulated areas. However, since the journey time routes in the Cotswold area do not compete with any routes in the model's buffer area, it may not be necessary to update buffer link speeds in this case.

3.4 Connector Coding

The internal zoning system mainly uses standard spanning connectors, which distribute trips along a link. While stub connectors can better represent zone-to-network interaction in dense urban areas, a selective review near strategic allocations is recommended. However, the review indicates that spanning connectors remain more appropriate overall, given the low density and rural nature of the Cotswold District.

3.5 Sector and Zoning System

Based on the GC3M development, the Cotswold District is currently divided into six sectors, each comprising groups of model zones that allow inputs and results to be conveniently aggregated for review and analysis. These sectors are:

- Cirencester (10 zones)
- Cotswold South (20 zones)
- Cotswold Central (29 zones
- Cotswold East (15 zones)
- Cotswold West (4 zones)
- Cotswold North (11 zones)

The size of model zones is an important consideration, as it defines the spatial area within which trips are generated and attracted. Larger zones concentrate more demand into a single network loading point. TAG guidance (Unit M3.1, section 2.3.11) suggests that the number of trips entering or leaving a zone should typically be limited to 200-300 per hour, to avoid such overloading. By contrast, smaller zones provide greater detail and allow more accurate representation of trip origins and destinations, particularly in areas of interest.

Therefore, large development sites would benefit from their own dedicated zones in line with the assumptions set out in Table 3-1. This ensures that development-related trips can be isolated and analysed independently, rather than being merged with surrounding demand that may exhibit different trip characteristics. Specific connectors can then be assigned to accurately represent access to and from the development.

To support this, CDC has provided a list of potential major settlements at the time of this report (see Figure 3:2) These sites have been used to inform the proposed zoning structure.

Assumption	Proposed Approach Taken
0 – 9 dwellings / jobs	Not specifically modelled- included as part of background growth.
10 – 500 dwellings / jobs	Development applied to current GC3M Zones.
500+ dwellings / jobs	Development is modelled fully. Allocated to its own zone with specific network and accesses modelled.

Table 3-1 Zoning Approach for Different Development Sizes

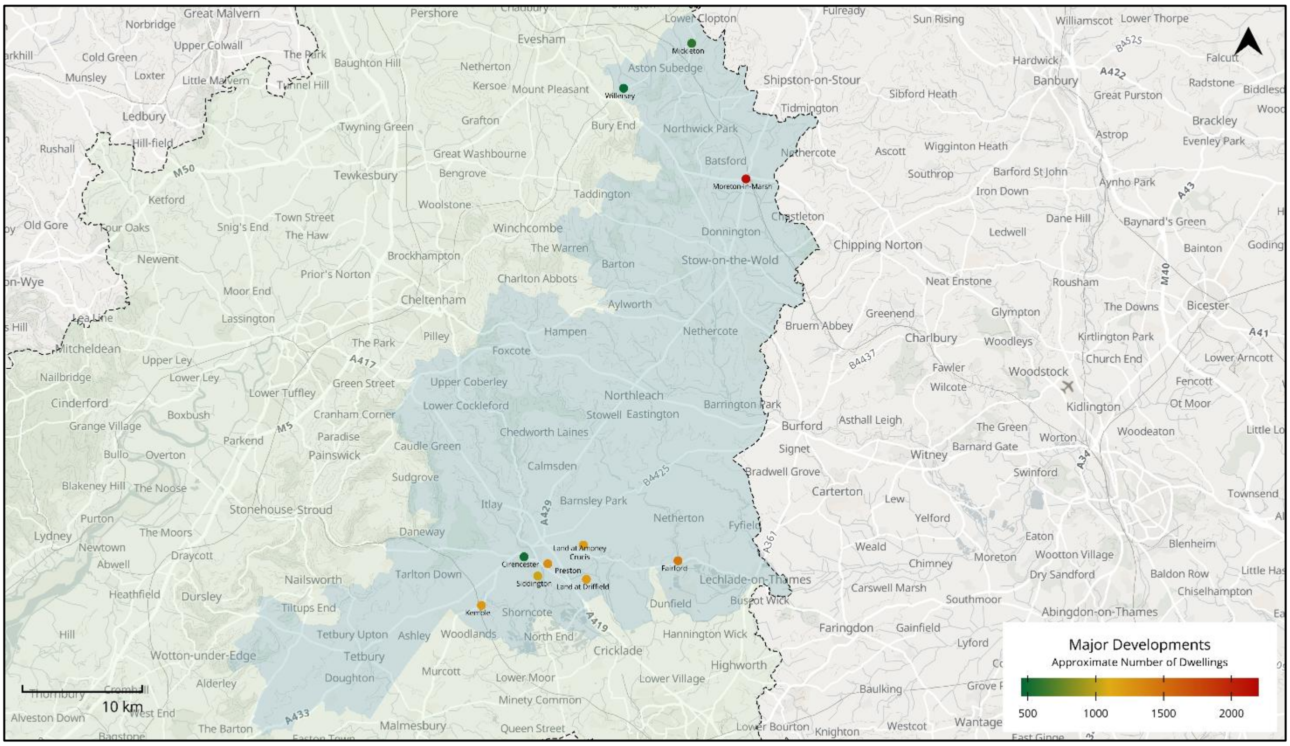

Figure 3:2 Location of the Major Developments

4 Calibration & Validation

4.1 Highway Calibration & Validation Summary

The model has been assessed against DfT's TAG calibration and validation standards.. For link flow validation, the following measures were used:

- The GEH statistic, which is a commonly used measure in transport modelling to assess discrepancies between modelled and observed flows, incorporating both relative and absolute errors.
- The absolute and percentage difference between modelled flows and observed counts.

According to TAG guidance, a link is generally considered to pass if it meets either the GEH threshold of less than 5 or satisfies the 'TAG Flow' criterion (as set out in Table 4-1).

Type	Description of Criteria	Acceptability Guideline
1	Individual flows within 100 vehicles/hour of counts for flows less than 700 vehicles/hour	>85% of cases
	Individual flows within 15% of counts for flows from 700 to 2700 vehicles/hour	>85% of cases
	Individual flows within 400 vehicles/hour of counts for flows more than 2,700 vehicles/hour	>85% of cases
2	GEH < 5 for individual flows	>85% of cases

Table 4-1 Acceptability guidelines for link flow validation (Source: TAG Unit M3.1 (3.2.8, Table 2))

For screenline flow validation, TAG requires that all or nearly all (95%) screenlines have differences between modelled flows and observed counts of less than 5% of the counts.

For Journey Time routes, TAG requires that at least 85% of routes have modelled times within 15% of surveyed times (or within 1 minute, where this is greater than 15%).

4.1.1 Analysis of Results:

Figures 4.1, 4.2, and 4.3 summarise the performance of the GC3M 2019 base model in the Cotswold District for the AM, IP and PM time periods.

- Calibration performance is very strong across all modelled periods, with 100% of screenlines passing the <5% difference test and over 85% of links meeting either the GEH or flow criterion. This indicates that the model is well calibrated to observed data.
- Validation performance is slightly weaker, as would be expected, but still within TAG acceptability ranges. Validation screenlines show strong results in the AM and PM (100% pass), though performance in the IP is lower (50% pass, 50% near).
- For validation link flows, between 70–72% of links pass the GEH <5 criterion, with a further proportion falling into the 'near' category. When combining GEH and flow criteria, overall validation success rates rise to 85–94% across periods, indicating the model represents observed traffic patterns reasonably well.
- Journey time validation is excellent, with 100% of routes passing the <15% difference threshold across all time periods.

Overall, the GC3M 2019 base year model meets most of the TAG calibration and validation criteria, providing confidence in its ability to represent traffic conditions in the Cotswold district.

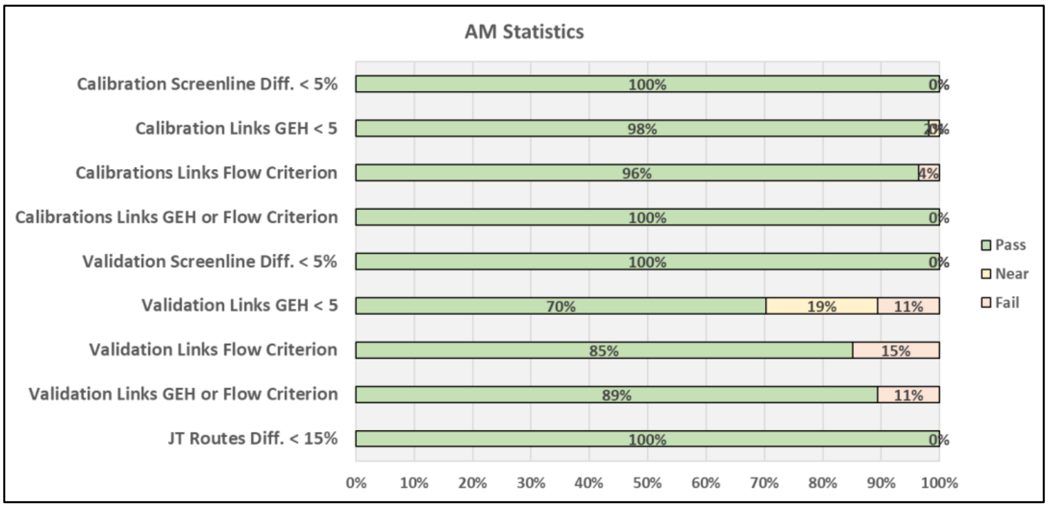

Figure 4:1. AM Calibration and Validation Summary Statistics

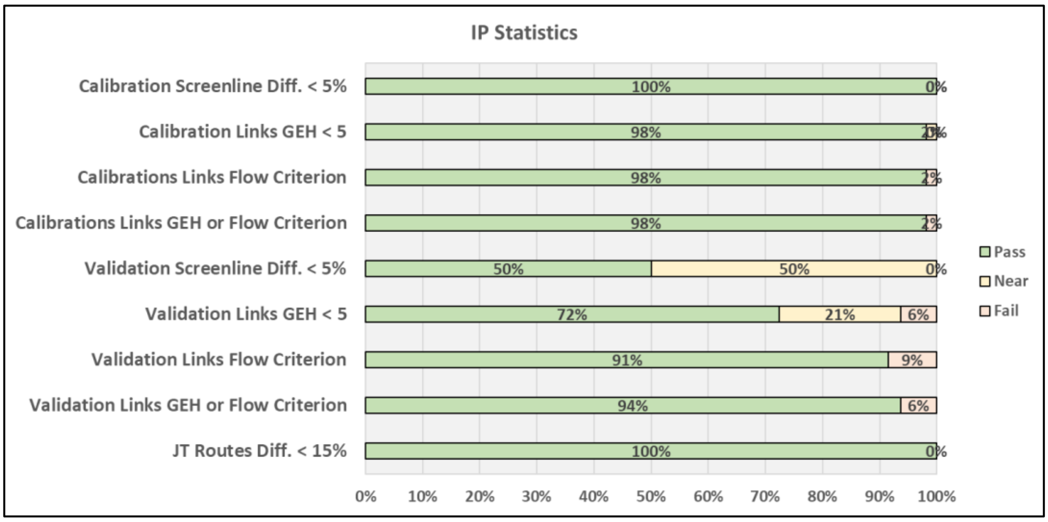

Figure 4:2 IP Calibration and Validation Summary Statistics

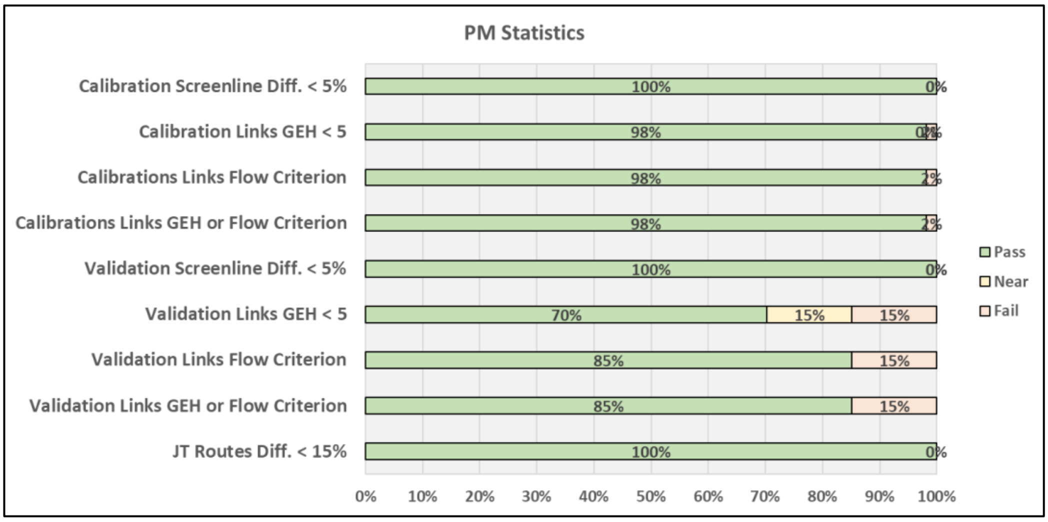

Figure 4:3 PM Calibration and Validation Summary Statistics

4.2 GEH Performance Near Potential Major Development Sites

4.2.1.1 Context and Findings

The GEH performance for each modelled period is summarised in Figures 4.4, 4.5, and 4.6, which highlight model count locations with GEH <5 shown in green, 5 ≤ GEH <10 in orange, and GEH ≥10 in red. Reviewing traffic count sites near major development locations is important to identify modelled flows that may require improvement to better reflect existing traffic conditions.

Most links across the district are green, indicating that modelled flows are very close to observed counts and meet TAG standards. A smaller number of links are orange, showing moderate discrepancies, while only a few are red, where modelled flows diverge more significantly from observed counts.

The orange and red GEH results are concentrated around Cirencester, Siddington, Preston, Moreton-in-Marsh, and Willersey in all three time periods, with additional discrepancies observed in Mickleton during the AM peak. Addressing these discrepancies will help strengthen the model and ensure it provides a more robust and reliable assessment of development impacts.

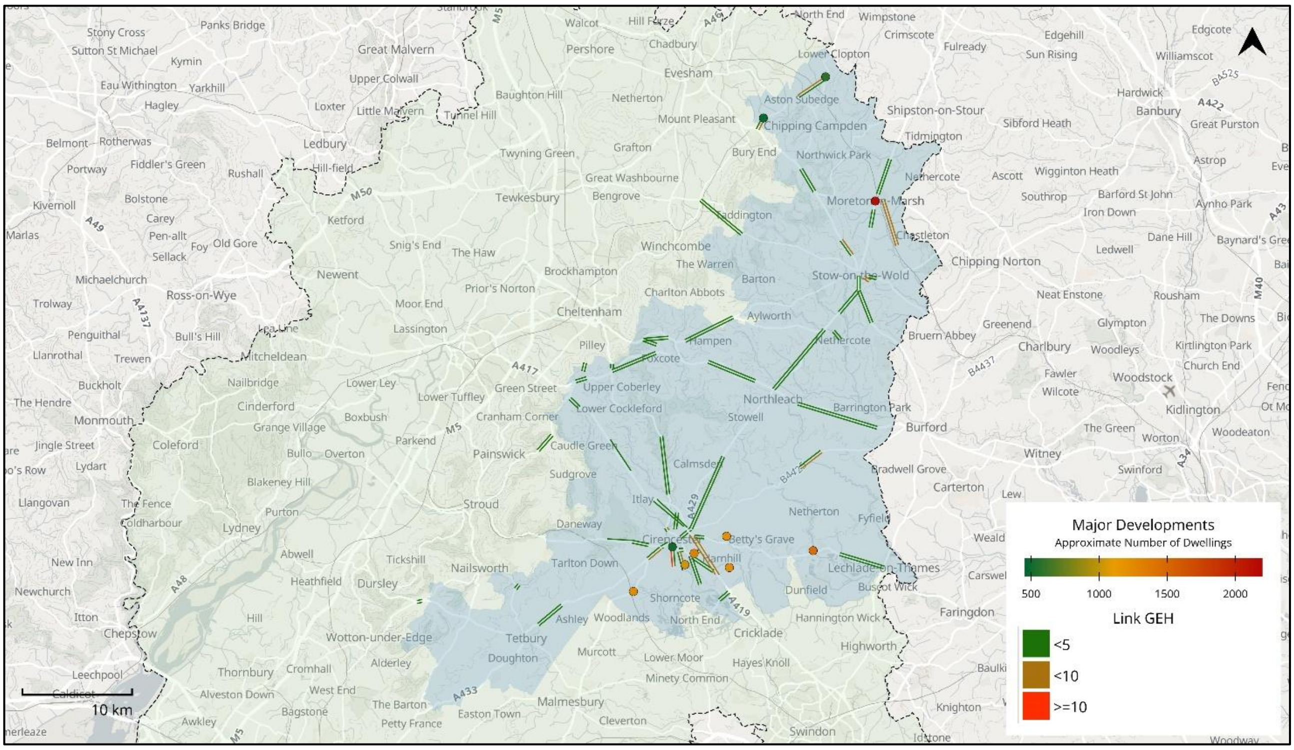

Figure 4:4 AM Peak GEH Performance Near Potential Major Development Sites

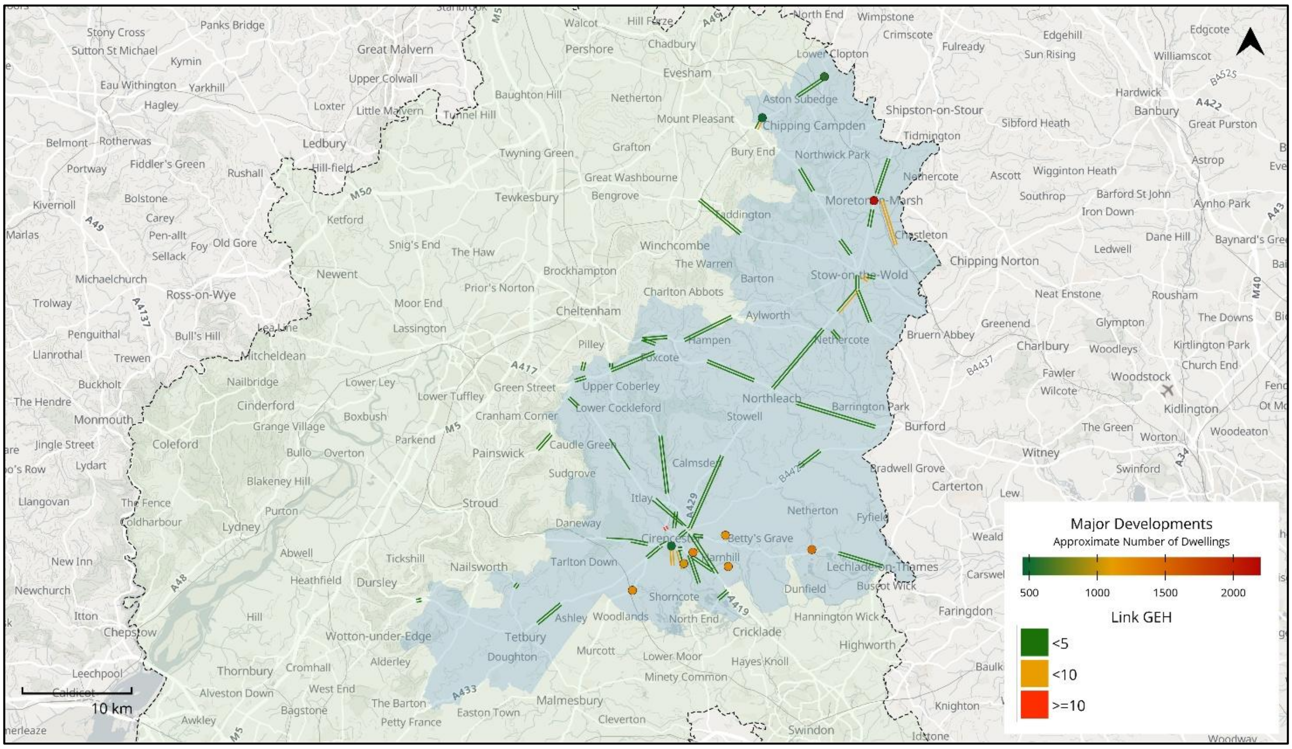

Figure 4:5 Inter-Peak GEH Performance Near Potential Major Development Sites

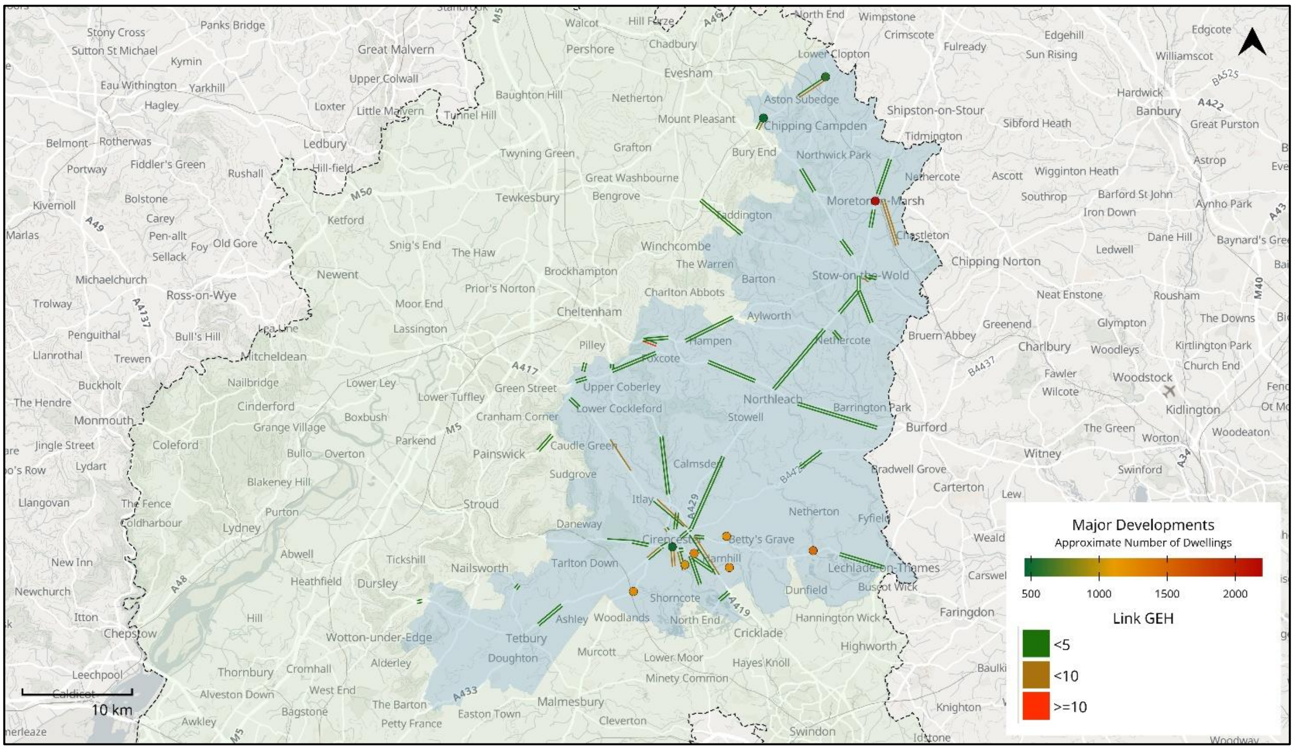

Figure 4:6 PM Peak GEH Performance Near Potential Major Development Sites

4.3 Public Transport Calibration & Validation Summary

4.3.1 Rail

In the Cotswold District, there are only two railway stations: Kemble and Moreton-in-Marsh. Moira data at the hourly level was used to calibrate the station entries and exits. The calibration results for each modelled period are presented in Tables 4.2 to 4.7. TAG requires that, for all or nearly all individual railway stations, the difference between observed and modelled entries and exits should be less than 25%, except where flows are below 150 passengers per hour, in which case the GEH statistic applies. The results show that both railway stations meet the GEH criteria; however, noticeable differences remain between the observed and modelled values. For validation, the annual calculated entries and exits of each station were compared with ORR data. This revealed a significant difference of 71% for Moreton-in-Marsh (refer to Table 4-8). It is recommended that further adjustments be made to improve alignment with the ORR figures.

Name	Observed Entry	Modelled Entry	% Diff	GEH	Absolute Difference	Pass / Fail (% diff <= 25%; GEH <5 if flow <150)
Kemble	91	53	-42%	5	-38	Pass
Moreton In Marsh	61	36	-41%	4	-25	Pass

Table 4-2 AM Rail Entries Calibration

Name	Observed Entry	Modelled Entry	% Diff	GEH	Absolute Difference	Pass / Fail (% diff <= 25%; GEH <5 if flow <150)
Kemble	36	20	-44%	3	-16	Pass
Moreton In Marsh	23	13	-44%	2	-10	Pass

Table 4-3 IP Rail Entries' Calibration

Name	Observed Entry	Modelled Entry	% Diff	GEH	Absolute Difference	Pass / Fail (% diff <= 25%; GEH <5 if flow <150)
Kemble	46	33	-28%	2	-13	Pass
Moreton In Marsh	26	17	-36%	2	-9	Pass

Table 4-4 PM Rail Entries' Calibration

Name	Observed Entry	Modelled Entry	% Diff	GEH	Absolute Difference	Pass / Fail (% diff <= 25%; GEH <5 if flow <150)
Kemble	58	46	-21%	2	-12	Pass
Moreton In Marsh	17	11	-36%	2	-6	Pass

Table 4-5 AM Rail Exits' Calibration

Name	Observed Entry	Modelled Entry	% Diff	GEH	Absolute Difference	Pass / Fail (% diff <= 25%; GEH <5 if flow <150)
Kemble	27	13	-54%	3	-15	Pass
Moreton In Marsh	24	16	-33%	2	-8	Pass

Table 4-6 IP Rail Exits' Calibration

Name	Observed Entry	Modelled Entry	% Diff	GEH	Absolute Difference	Pass / Fail (% diff <= 25%; GEH <5 if flow <150)
Kemble	8	4	-49%	2	-4	Pass
Moreton In Marsh	50	23	-54%	4	-27	Pass

Table 4-7 PM Rail Exits' Calibration

Name	Yearly Observed	ORR	% Diff
Kemble	384208	409170	-6%
Moreton In Marsh	171211	292544	-71%

Table 4-8 AM Rail Entries Validation

4.3.2 Bus

Bus passenger flow validation was carried out at the sector level by grouping stops within each sector. TAG requires that, for all or nearly all stops, the difference in boardings and alightings between observed and modelled values should be less than 15%, with the GEH statistic applied where flows are low. Tables 4.9 to 4.11 present the results for the Cotswold sectors across each modelled period. Cirencester, notably, fails to meet the 15% criterion and does not satisfy the more flexible 25% threshold. Cotswolds central also fails to meet both criteria in the PM. As Cirencester is a key urban area within the Cotswold District, improvements should be prioritised there, alongside adjustments to better represent passenger flows in the Cotswolds Central sector.

Sector	Observed Boardings	Modelled Boardings	% Diff	GEH	Absolute Difference	Pass / Fail (% diff <= 15%; GEH <5 if flow <150)	Pass / Fail (% diff <= 25%; GEH <5 if flow <150)
Cotswold Central	100	64	-36%	4	-36	Pass	Pass
Costwold East	64	67	4%	0	2	Pass	Pass
Cotswold South	54	42	-22%	2	-12	Pass	Pass
Cirencester	16	57	258%	7	41	Fail	Fail
Cotswold West	1	1	61%	0	0	Pass	Pass

Table 4-9 AM Bus Boardings Validation

Sector	Observed Boardings	Modelled Boardings	% Diff	GEH	Absolute Difference	Pass / Fail (% diff <= 15%; GEH <5 if flow <150)	Pass / Fail (% diff <= 25%; GEH <5 if flow <150)
Cotswold Central	97	128	32%	3	31	Pass	Pass
Costwold East	44	44	1%	0	0	Pass	Pass
Cotswold South	26	21	-18%	1	-5	Pass	Pass
Cirencester	25	62	142%	5	36	Fail	Fail
Cotswold West	0	1	178%	1	1	Pass	Pass
Cotswold North	1	1	19%	0	0	Pass	Pass

Table 4-10 IP Bus Boardings Validation

Sector	Observed Boardings	Modelled Boardings	% Diff	GEH	Absolute Difference	Pass / Fail (% diff <= 15%; GEH <5 if flow <150)	Pass / Fail (% diff <= 25%; GEH <5 if flow <150)
Cotswold Central	64	15	-77%	8	-49	Fail	Fail
Costwold East	36	36	-1%	0	0	Pass	Pass
Cotswold South	15	14	-2%	0	0	Pass	Pass
Cirencester	8	69	772%	10	61	Fail	Fail
Cotswold West	0	2	998%	2	2	Pass	Pass

Table 4-11 PM Bus Boardings Validation

5 Public Transport Fare & Journey Time Elasticities

5.1 Overview

The public transport (PT) fare elasticity test examines how PT trip-making, across all sub-modes, responds to a 10% increase in both bus and rail fares, applied consistently across all demand segments.

5.2 Model Performance

The modelled elasticities are broadly in line with TAG Unit M2.1 guidance, though some deviations have been identified that may warrant further review:

- **Bus Fare Elasticity:** The modelled elasticity is -0.2, which lies at the lower end of the typical TAG range (-0.2 to -0.9 for public transport trips and −0.35 to −0.9 for bus trips for full fare paying passengers) and below the recommended value of -0.4 for bus sub-mode choice. This suggests that the model may understate bus users' sensitivity to fare changes, potentially limiting its responsiveness to pricing interventions. However, it is noted that that around 25% of the daily ticket sales within Gloucestershire are free journeys which would impact the derived elasticities.
- **Rail Fare Elasticity:** It is noted that the latest TAG includes sub-mode elasticities (-0.7 to-1.5), which were not available at the time of 2019 model build. However, the modelled elasticity is higher than expected relative to TAG guidance, indicating that demand appears overly responsive to rail fare increases. This could result in exaggerated mode shift away from rail and reduce the reliability of rail demand forecasts under fare change scenarios. It is noted in the MDVR that further improvements can be done to better match synthetic and assignment matrices. The MDVR also notes that the rail passenger demand levels are relatively small when compared to the total trips and no proposed rail use cases were identified at the time of model development.

5.3 Conclusion

The model generally performs well. Further calibration could be considered to better align fare elasticities with TAG, although limitations should be noted.

6 Variable Demand Model

6.1 Key Results

The Variable Demand Model (VDM) results show differences between the synthetic and final assigned models, suggesting that the demand responses such as modal shift are not well replicated. This will be important given the focus on sustainable transport measures as part of the Cotswold Local Plan and capturing demand changes accurately. This highlights a need for further monitoring, with a view to identifying refinements if required, particularly regarding how mode shift and trip length are represented. Section 6.14 of the MDVR report discusses the different pivoting processes that are used, depending on the relative difference between synthetic and assignment trips at a zonal level. These are chosen per-zone and are dependent on values of these parameters. The intention is to use the standard Absolute Model Applied Incrementally whenever possible though to fall back to an additive function where required.

Time Period	HAM Matrix Total	VDM Matrix Total	Difference	% Difference
AM Peak	97,726	86,271	-11,456	-12%
IP Peak	72,915	57,201	-15,714	-22%
PM Peak	106,901	101,851	-5,050	-5%

Figure 6:1 Comparison of Total Matrix Sizes for Car (VDM vs final HAM, both vehicle trips)

Mode	Time Period	PT AM Matrix Total	VDM Matrix Total	Difference	% Difference
Bus	AM Peak	4,842	4,007	-835	-17%
	IP Peak	4,477	4,817	340	8%
	PM Peak	4,126	5,586	1,460	35%
Rail	AM Peak	1,551	2,720	1,169	75%
	IP Peak	800	762	-38	-5%
	PM Peak	1,597	2,481	884	55%

Figure 6:2 Comparison of Total Matrix Sizes for public transport (VDM vs PTAM)

7 Recommendations & Conclusion

7.1 Recommendations

Several recommendations emerged from the review of the GC3M 2019 base model, including:

1. **Additional Journey Time Routes:** Introducing additional journey time routes to cover all the main roads in the area and enhance the reliability of the model, particularly around large sites under consideration such as in Mickleton, Willersey, and Moreton-in-Marsh.
2. **Signal Data Enhancement:** Correcting the identified issues at three signalised junctions where staging, timings, or saturation flows are inaccurate.
3. **Additional Zones:** Adding dedicated zones for each of the 10 potential development sites with high number of dwellings. This will ensure consistency with the future year structure and allow site to be fully modelled with its own zone and associated connectors.
4. **Enhancing count validation:** Improving validation of traffic counts, particularly around major development sites, including Cirencester, Siddington, Preston, Moreton-in-Marsh, and Willersey, where GEH performance is weaker. This will help minimise discrepancies between modelled and observed flows and ensure the model provides a more robust assessment of development impacts.
5. **Improving Public Transport Validation:** Enhance the validation of rail stations, with a focus on Moreton-in-Marsh, to closely match the ORR values, and improve bus validation in the Cirencester area to bring results within the required criteria.
6. **Bus and Rail fare elasticities:** The modelled elasticities are broadly in line with TAG Unit M2.1 guidance, though some deviations have been identified that may warrant further review. We note that the bus sub-mode fare elasticity is outside the TAG range however it is noted that that around 25% of the daily ticket sales within Gloucestershire are free journeys which would impact the derived elasticities, therefore no further action is needed. In addition, the rail sub-mode fare elasticity is higher than the TAG range but it is noted that rail demand constitutes a small proportion of total trips, we therefore don’t intend to make changes as we think the resultant adjustment would have minimal impact.
7. **VDM:** Given the observations regarding the VDM it is recommended to benchmark the forecast modal splits and shift against available datasets such as NTS (i.e. modal split) and observed modal shifts from outturn data when equivalent polices are enacted.

7.2 Conclusion

The GC3M demonstrates a generally good level of performance, meeting most TAG criteria for calibration and validation. Some refinement is possible on the demand side; for example, VDM results show differences between synthetic and assigned demand. Similarly, the average trip length between prior and post matrix estimation could be improved to fully meet TAG criteria, although some deviation on demand-related criteria is common. Targeted enhancements, particularly near large developments, would further strengthen model reliability and forecasting accuracy, reinforcing its value as a robust evidence base for future decision-making.

In summary, this note highlights key aspects of the GC3M that may benefit from refinement or ongoing monitoring during the Cotswold local plan strategic transport assessment. Overall, the GC3M demonstrates good performance, but areas for improvement have been identified. Enhancements around the potential strategic site allocations are recommended, and further localised assessments of the model’s network structure, zoning, calibration, and validation will be carried out.