Supported by

Bus Back Better Support Programme

Support Package 2
Data analysis, monitoring and evaluation

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Transport for the South East, Transport East and England's Economic Heartland

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1 Introduction

This technical note is one of a series produced as part of the joint project commissioned by three Sub-National Transport Bodies (STBs), England's Economic Heartland (EEH), Transport East (TE) and Transport for the South East (TfSE), to help support Local Transport Authorities deliver the government's National Bus Strategy for England ('Bus Back Better'). To deliver this strategy, the government has invited Local Transport Authorities (LTAs) and bus operators to formally collaborate and work with stakeholders and bus users to identify, and then implement, initiatives that will improve bus services and attract new users. It is envisaged that these improvements will be delivered through Bus Service Improvement Plans (BSIPs), Enhanced Partnership (EP) schemes, and franchising.

1.1 Background

The Department for Transport (DfT) has identified some additional funding to support its key priorities. There are four areas where STBs could undertake further work:

- **Decarbonisation:** Helping the DfT and Local Authorities (LAs) to implement the commitments made in the Transport Decarbonisation Plan.
- **Buses:** Helping LAs to deliver on the commitments in Bus Back Better and develop an effective intra-regional bus network.
- **Electric Vehicle (EV) Infrastructure Strategy:** Assisting LAs in the rollout of EV infrastructure, potentially through regional strategies.
- **Local Authority Capability:** Playing a role in building capability within resource- constrained LAs, to help them in the planning and delivery of local transport.

Three STBs, EEH, TE and TfSE, have joined forces to deliver a package of work to assist LTAs within the three regions with the delivery of their BSIPs and implementation of their EPs. The LTAs are:

- **England's Economic Heartland:** Bedford, Buckinghamshire, Cambridgeshire, Central *Bedfordshire**, *Hertfordshire**, *Luton**, Milton Keynes, North Northamptonshire, *Oxfordshire**, Peterborough, Swindon, West Northamptonshire.
- **Transport East:** *Norfolk**, Suffolk, Essex, Southend-on-Sea, Thurrock.
- **Transport for the South East:** Bracknell Forest, *Brighton & Hove**, *East Sussex**, Hampshire, Isle of Wight, *Kent**, Medway, *Portsmouth**, *Reading**, Slough, Southampton, Surrey, Windsor & Maidenhead, Wokingham, *West Berkshire**, *West Sussex**.

(indicates an LTA that has received BSIP funding)*

The project supports all the LTAs whether they have received DfT funding for their BSIPs or not.

The project is split into two stages. The initial stage of the project – **triage and prioritisation** – ran from August to December 2022. It took stock of LTAs' current progress in delivering the BSIPs and scoped the work programme for future delivery activities. Online workshops were held in September 2022 and provided a forum for LTAs and bus operators to discuss their aspirations and explore themes, priorities, challenges, and potential solutions. The project is ensuring that opportunities for technical pieces of work that would benefit multiple authorities are identified and progressed.

The second stage of the project – **implementation** – involves the delivery of support packages for the following topics that were identified during Stage 1:

- Support Package 1: Fares and Ticketing
- Support Package 2: Data Analysis, Monitoring and Evaluation
- Support Package 3: Low Cost and Quick Win Solutions
- Support Package 4: Building a Strong Case
- Support Package 5: Infrastructure and Road Space
- Support Package 6: Demand Responsive Transport
- Support Package 7: Rural Hubs and Integration
- Support Package 8: Funding Mechanisms
- Support Package 9: Collaborative Working
- Support Package 10: Marketing
- Support Package 11: Alternative Fuels and Low Emission Vehicles

Support will be delivered using a mix of channels, including webinars, toolkits and guidance, case studies and one to one support. It will also include establishing bus forums in each of the three STB areas to promote efficiency, avoid duplication of effort, share knowledge and best practice, and identify where joint working would be productive. The technical work will be undertaken to collate evidence and research. The emphasis will be on a regional approach so that common themes can be identified but localised assistance will be available to improve capacity in LTAs and provide specialist inputs regarding local issues.

1.1.1 Intended outputs and outcomes

Project Outputs: Improved delivery of BSIPs and EPs, and support to LTAs who have not received government funding in the current round. This will include:

- Enhanced evidence base through research papers on prioritised knowledge gaps;
- Knowledge sharing within and between STBs and their constituent members and between the public and private sectors; and
- Better resourced LTAs through prioritised third-party support, provided in targeted areas.

Project Outcomes: These outputs will seek results in outcomes aligned to the National Bus Strategy including:

- Increased patronage;
- Enhanced accessibility and social inclusion;
- Reduced carbon emissions and improved public health; and
- More commercially sustainable bus networks.

TfSE is managing the project on behalf of the three STBs. A consultant consortium of Mott MacDonald and Arup is delivering the project. A Steering Group has been established, comprising the DfT, the three STBs, representatives from some of the LTAs, and Mott MacDonald and Arup.

1.2 Overview

This technical note forms part of Support Package 2: Data analysis, monitoring and evaluation. The National Bus Strategy requires that east LTA's BSIP places a focus on improving bus patronage, for which evidence is needed both to assess what improvements are most appropriate and to measure their effectiveness. As such, this Support Package focuses on providing advice and a practical toolkit for LTAs regarding data analysis, monitoring, and evaluation to demonstrate how data should be used. This note places a particular focus on the following Key Performance Indicators (KPIs) which are used to monitor, evaluate and improve bus services:

- Number of users (from ticket data) which is essential to monitor the number of users by day/service/journey to understand fully current travel patterns and emerging trends;
- Customer satisfaction (surveys) which are important to find out what users think about the service;
- Service performance (punctuality) to understand if journey times are consistent and adhere to the published timetable;
- Journey purpose to identify where people are using the bus, particularly new users; and
- Non-user surveys to identify what would support the decision to use the bus which is important to generate new users.

The KPIs cover both how the service is being provided (reliability, punctuality and the quality of service) and the views of users and non-users (survey information covering users' views on the quality of the service e.g. value for money, journey times, driver interface with customers). However, the main KPI will be the number of users and showing how many more passengers are using the service, which can be disaggregated in a number of ways to better understand which services are the most popular and relate to specific improvements.

This technical note is set out as follows:

- **Section 2:** provides an overview of data range and availability;
- **Section 3:** presents methods for the analysis of baseline patronage and forecasting into the future;
- **Section 4**: covers the principles and methods for the monitoring of bus data against performance indicators; and
- **Section 5:** outlines the principles and methods for evaluating the value of interventions.

2 Data range and availability

In the past, measuring public transport performance could be difficult and collecting the data necessary to evaluate local bus performance was very costly. A number of performance measures have been traditionally calculated from information an operator would normally have on hand for other purposes, like scheduling data, system maps, service design standards, accident and incident records, financial data, fleet data, complaint records, and so on. In addition, data was provided by the Department for Transport and other transport bodies.[1] As a result of the widespread implementation of Intelligent Transportation Systems (ITS) data collection is no longer a limiting factor.

Nowadays, a large amount of data is provided by Automated Vehicle Locators (AVL), which detect in real time a vehicle's location to calculate schedule deviation information, and Automatic Passenger Counters (APC), which allow passenger boarding and alighting to be detected by means of infrared sensors and optical imaging.

The Department for Transport (DfT) provide the open-source platform Bus Open Data Service (BODS), which includes information on bus timetables, vehicle location and fares. Bus operators and local authorities have access to Analyse Bus Open Data (ABOD) which provides dahsboards of datasets.

There are various ticketing systems in use, most of which enable multi-media tickets and record every transaction made in detail. Multi-media tickets refers to the range of ways that users can pay for their fare, which includes traditional paper tickets, contactless payment, mobile phone NFC payment, QR code payment, smart cards, and cash. This information includes origin (boarding stop location) and often destination (alighting stop or fare stage) or enable this to be deduced from the fare paid. This data is very valuable because it can identify the volume of trips made between all origin-destination pairs throughout the day.

Transport Focus, an independent watchdog for transport users sponsored by DfT, undertakes customer satisfaction surveys, but they are irregular. However, they provide the framework for survey questions and maintaining this format would be helpful for more regular surveys.

2.1 Key performance indicators

2.1.1 Number of farepayers

The aim of Bus Back Better is to generate more demand for bus services and therefore have a higher number of farepayers. For this, the most basic indicator is the number of people using the bus. This indicator can be provided at various levels from an agglomerated group of services or at local authority level, to individual services and individual journeys by day.

This helps to identify travel behaviour by day of the week, season and annually, noting that trends may be difficult to identify given that large fluctuations in demand could be due to a variety of reasons. Trends can be identified more reliably with longer time series.

2.1.2 Number of concession users

The National Concessionary Travel Scheme (NCTS) for England provides free travel for people from state pension age and for disabled people and their escorts. Although free to use (with

[1] Performance indicators for an objective measure of public transport service quality European Transport \ Trasporti Europei (Year) Issue 51, Paper n° 3, ISSN 1825-3997

some locally-defined restrictions), NCTS is funded by central government funding allocations to local authorities which then reimburse operators on the basis of the number of transactions made. Adding the number of farepayers and NCTS users, the total number of users can be identified definitively.

Because the scheme offers free travel to certain groups, there is likely to be a greater propensity to use bus services than farepayers. However, concessionary journeys are lower in number than before the Covid-19 pandemic, likely because of fear of contracting viral infections such as Covid-19 or similar when using buses.

2.1.3 Punctuality

The main indicator of performance is punctuality. This is typically measured by the proportion of journeys operated that arrive on time. 'On time' is defined by the Traffic Commissioner as being no more than one minute early or five minutes later than the published timetable.

Delays can occur for a variety of reasons; in some cases it is due to predictable reasons such as traffic congestion or planned road works, and timetables are or can be adjusted during peak hours to accommodate for delays due to traffic to ensure that the service is still punctual. Unplanned delays, however, lead to passenger dissatisfaction and can contribute to falling patronage if bus arrival/departure times and journey times are chronically unreliable. Using punctuality data can help operators identify trends in journey reliability and adjust timetables accordingly so that bus users can plan their journeys and days better. The data also provides evidence in support of proposals for bus priority and related measures.

Detailed punctuality data is available for journeys where vehicle location equipment is fitted and so can be determined at a fine level throughout a journey. As with other data, daily summaries can be a useful means of avoiding too much information but can be interrogated further if required.

2.1.4 Customer surveys

Customer surveys provide valuable information about the reasons people choose to use buses and their views on all aspects of the service and potential improvements. Aspects cover punctuality, pricing, comfort and a range of other details, all of which provide an insight to the customers experience and can be used as evidence to support proposals that improve the service.

A key aspect that is identified through surveys is journey purpose, i.e., why people are travelling by bus. Some reasons may be evident by location e.g. a school or hospital but further information is helpful, e.g. staff travelling regularly. The main reasons for travelling by bus pre-pandemic included journeys to work and shopping, both of which have reduced since. Other journeys are made to access education and healthcare; leisure trips by bus may have increased as they have on the railway.

Identifying the journey purpose is important for service planning. Many networks focus on an urban centre with radial routes and fewer orbital routes. This pattern may need to be revised given changes in land uses and new development taking place which may require different services. Traditionally, services have aimed to accommodate a variety of purposes but this may no longer be the case and some stratification may be appropriate.

2.2 Data Sources

Whilst there is a wide range of publicly available data, there isn't a 'one-stop-shop' where the main bus performance metrics can be viewed. Data needs to be sourced from the relevant

government agencies (such as DfT or ONS), operators, and independent researchers (such as Transport Focus).

Bus operators in England and outside of London are required to collect bus data and provide it to DfT. This includes up to date timetables, fare information and real-time vehicle location data. Transport Focus undertakes customer surveys to collect qualitative data about the experience of bus users. General population data is also useful in planning for and assessing bus services, and this is best sourced from the Office of National Statistics (ONS).

2.2.1 Department for Transport - statistical datasets

The DfT holds data and statistics about the local bus sector, usually broken down at high levels such as country, region, and local authority. The bus statistic data tables are released annually, except for England-level fares data, which are released quarterly. Datasets broken down by local authority include:

- Passenger journeys;
- Vehicle distance travelled; and
- Reliability and punctuality.

Bus statistics data tables can be found on the GOV.UK website at the following address:

https://www.gov.uk/government/statistical-data-sets/bus-statistics-data-tables

2.2.2 Bus Open Data Service (BODS)

The Bus Open Data Service (BODS) is a DfT-funded service in England, established in 2020 as part of the Bus Services Act 2017. The Bus Open Data Service provides bus timetable, vehicle location and fares data for every local bus service in England in an open-access, open-source platform. Data is uploaded by operators using a standardised framework. BODS is the database for which Analyse Bus Open Data (ABOD) serves as its front-end and dashboard.

BODS datasets are very large and require data cleaning, sorting and analysis using specialised software such as PowerBI to extract meaningful information from it.

2.2.3 Analyse Bus Open Data (ABOD)

The platform shows granular, service-level and stop-level on-time performance, helping local authorities and operators to understand which routes have the most potential for improvement. Excess waiting time reporting shows the impact of irregular headways and cancellations on the passenger experience. Pinch point analysis along customisable corridors inform infrastructure changes, deployment of bus priority and town centre management.

ABOD access is limited to bus operators and local authorities. Operators and authorities who have not received an invitation to get access to ABOD or do not know their details to access it can request this by emailing BusOpenData@dft.gov.uk.

2.2.4 Office of National Statistics

Results from the decennial census of England and Wales are made available online through the Nomis online service. This provides census data that has been analysed and summarised for different areas in England that may be relevant to bus planning, such as bus stop catchment populations and method of travel to work data. This data can be downloaded in table format from the Nomis website (https://www.nomisweb.co.uk/) and matched with the relevant GIS boundaries which can be found on the ONS Open Geography Porta (https://geoportal.statistics.gov.uk/).

To do this, GIS software such as ArcGIS or QGIS is required to load, analyse, format and export the maps.

2.2.5 Operator data

Data from operators is invaluable when filling in potential gaps from other sources. Operators may be able to provide granular patronage data down to the stop-level, however this data may be commercially sensitive and is not suitable for publication. Some operators may also have satisfaction data for specific services or corridors.

It is recommended that as part of negotiations establishing Enhanced Partnerships with bus operators, LTAs outline datasets that all operators within their area should make available to them to help plan for investments in bus infrastructure and services.

2.2.6 Transport Focus

Transport Focus is an independent watchdog representing the interests of Britain's road, rail, tram and bus users. This organisation leads advocacy campaigns with evidence generated by in-house research and analysis and undertakes regular surveys for bus users. Transport Focus provides two useful datasets of bus customer satisfaction:

- Bus User Weekly Survey at a national level; and
- Bus Passenger Survey at a local authority level with annual reporting (not including 2020 or 2021)

2.3 Existing datasets

A summary of key existing datasets is presented in Table 2.1 below.

Table 2.1: Existing datasets sources

Data Type	Dataset	Source	Link
Demand	Passengers on local bus services by LA in England from 2009/10 onwards	DfT	bus01.ods (live.com)
	Passenger journeys on local bus services per head by LA in England from 2009/10	DfT	bus01.ods (live.com)
	Elderly and disabled concessionary passenger journeys on local bus services by LA, England from 2009/10	DfT	bus01.ods (live.com)
	Elderly and disabled concessionary passenger journeys on local bus services by LA as a % of total bus journeys, England from 2009/10	DfT	bus01.ods (live.com)
Commercial	Estimated net support paid by central and local government (at current prices) for local bus services: England by local authority, annual from 2000/01	DfT	bus05i.ods (live.com)
	Estimated net support paid by central and local government (at constant prices) for local bus services: England by local authority, annual from 2000/01	DfT	bus05ii.ods (live.com)
On-street Performance	Non-frequent bus services running on time by local authority: England, annual from 2004/05	DfT	bus09.ods (live.com)

Data Type	Dataset	Source	Link
	Average excess waiting time for frequent services by local authority: England, annual from 2004/05	DfT	bus09.ods (live.com)
	On-time performance for local authority, operator, corridor or stop	ABOD	Analyse BOD
	Average delay per stop	ABOD	Analyse BOD
	Reliability, number of actual services against expected services	ABOD	Analyse BOD
	Average bus speed, by corridor or service	ABOD	Analyse BOD
Customer Feedback	Bus User Weekly Survey, England	TF	TF Data Hub
	Bus Passenger Survey at a local authority level with annual reporting	TF	TF Data Hub

2.3.1 Primary data collection

For LTAs and operators, primary data collection might be required. This is likely to understand local user views where there is no data available from Transport Focus, or where there is not enough resolution or granularity in the existing data available from other government agencies.

2.3.1.1 User views and demographics

The views of users are usually a secondary consideration in the absence of comprehensive data. However, it is vital to understand why people do or do not use bus services if improvements are to be effective in attracting more users. Occasional surveys of customer experiences are undertaken, but a series of more regular surveys is valuable and whilst they can be expensive to undertake, the results are highly informative.

Transport Focus has a bus passenger survey[2] which groups questions around the following themes:

- **About your journey**: including type of ticket, payment method, purpose of journey and the reason for choosing to travel by bus;
- **About the bus stop and where you boarded the bus:** what amenities were provided at the bus stop;
- **Waiting for the bus:** how long users waited against how long they expected to wait;
- **On the bus:** satisfaction with amenities on the bus, personal safety, length of the journey, and satisfaction with the bus driver;
- **Overall opinion of the journey:** value for money, satisfaction with the bus company;
- **Opinion of bus travel in your local area:** satisfaction with bus services e.g. to get to local amenities, frequency and reliability; and
- **About you:** a series of demographic questions.

If there is not a recent or regular survey of a specific area that is required for bus planning, it is recommended that LTAs work with Transport Focus to try to develop and conduct a survey of bus users.

[2] Transport Focus (2020) Bus Passenger Survey. Methodological overview – Autumn 2019 wave. Available at: https://d3cez36w5wymxj.cloudfront.net/wp-content/uploads/2020/03/10160210/Bus-Passenger-Survey-methodological-overview-Autumn-2019.pdf

2.3.1.2 Non-user groups

Non-user groups are largely absent in existing survey data for non-users, as it is generally something of an unlimited sample set (compared to the way bus users are an easily defined group). This is where growth in demand will come from so understanding individuals' needs and opinions is crucial to identifying initiatives that improve bus services and attract new users.

For example, car owners tend to travel by this mode habitually. As a result, creating a bus offer that can appeal to this user group can be difficult. Therefore, an understanding of the reasons why, when, and how people travel is essential if improved services are going to offer a viable alternative to car use.

Examples of key questions that could be asked to non-user groups include:

- Would you consider using the bus for [this particular] journey?
- Are you aware how often the bus departs and how long it takes?
- Have you a car available for the journeys you make?
- Do you know how much the bus journey could cost?
- Have you a designated parking space at your workplace?
- What would need to happen to make you use the bus?

2.4 Commercial sensitivities

Operators have detailed data about their services but are reluctant to share this information with others due to its commercial sensitivities and the possibility that another operator could identify a profitable service and establish a rival service.

However, there are many reasons why data should be shared:

- Operators are part of Enhanced Partnerships which require robust information to assess services and initiatives. The relative performance of services (number of users and likely revenue) is a fundamental requirement of an Enhanced Partnership, without which monitoring and evaluation cannot be undertaken;
- Data confidentiality can be achieved through the use of non-disclosure agreements (NDAs) within an Enhanced Partnership;
- Third party data analysis can draw out information that can be presented in an acceptable way e.g. consultant support can ameliorate some of the difficulties; and
- Current economic pressures mean that it is very unlikely that any operator will take on the risk of competing directly against another operator.

3 Analysis for baseline and forecasting

This section details different methods for the analysis of baseline patronage and forecasting this into the future. Realistic forecasting is dependent on understanding the spatial-temporal relationship between different variables in existing and historic data. However, real world passenger data can be random and unstable making it difficult to forecast future demand.

Accurate demand forecast predictions can, however, have wide-ranging benefits that can inform decisions about services including:[3]

- Reducing congestion;
- Improving service quality;
- Timetable reform and route planning;
- Informing policy makers when implementing transportation policies;
- Reduce excessive energy consumption and carbon emissions;
- Improve the urban ecosystem;
- Improve bus reliability; and
- Bus scheduling.

When choosing an appropriate model during the pre-planning stage, it is key to make sure that there is a full appreciation for the model's purpose and the factors required for modelling. Important elements such as alignment with TAG and carbon assessments should be considered. The ability to understand the model's purpose, limitations and requirements will be key to the value of future forecasting.

3.1 Methods of analysis for baseline and forecasting

There are three key methods that are commonly used to forecast bus patronage and within these umbrella methods are a number of different techniques that can be applied such as scenario testing or the use of elasticity measures. These three methods are:

- Non-assignment, spreadsheet based model;
- Regional highway and public transport model; and
- Agent-based model.

A summary of the core methods can be seen in Table 3.1.

[3] Cheng, C.H., Tsai, M.C. and Cheng, Y.C., 2022. An intelligent time-series model for forecasting bus passengers based on smartcard data. Applied Sciences, 12(9), p.4763.

Liyanage, S., Abduljabbar, R., Dia, H. and Tsai, P.W., 2022. AI-based neural network models for bus passenger demand forecasting using smart card data. Journal of Urban Management, 11(3), pp.365-380.

Table 3.1: Methods of analysis for baseline and forecasting

Method	Details	Techniques	Examples
Non-assignment, spreadsheet based model	• Spreadsheet tool applying scenarios assumptions / elasticities to existing patronage data • Small scale with limited scope for change • Limited compatibility to model carbon impacts	• Scenario testing • Elasticity	• Metropolitan Bus Model (MBM) • Corridor bus priority analysis • Park & Ride model
Regional highway and public transport model	• Traditional 4-stage model built using observed demand data • Validated to WebTAG criteria • Provides regional Origin – Destination matrices • Typically peak hours only	• Tests changes to networks • Assignment to routes • Mode-choice model • Time-choice model • Quantifies travel time changes, carbon emissions • Can translate model I data to micro-simulation model for testing infrastructure / junction changes	• Policy Responsive Integrated Strategy Model (PRISM) • TfL Motion • National Highways RTMs • TfL HAMS
Agent based model	• Model individual users of the transport network and their choices • Better reflect unique travel preferences and constraints depending on agency • Useful for demand responsive modelling • Not currently discussed in TAG and use for supporting schemes is untested • Provide a tool to generate model outputs to highlight carbon emission hotspots	• Scenario testing • Time based model	• Suffolk ABM Alpha (Arup) • TII ABM (Arup)

3.2 Methods

3.2.1 Non-assignment spreadsheet model

This type of spreadsheet model is a standalone tool which contains information about base year public transport demand and can predict how this will change in the future based on certain assumptions.

In its simplest form this tool could take existing travel times, patronage, and fares, and assess impacts of changes to the generalised costs of travel (such as fare changes or improved speeds) – using elasticity techniques.

It is not recommended that this tool incorporates full public transport assignment, but a mode share function could be included to predict passenger share between competing bus routes or modes within the same corridor.

More complex modelling theory such as mode choice or revenue, could be incorporated into the tool, however, other models are considered more efficient. Similarly, impacts on other modes would be difficult to predict with this approach.

Urban Transport Group's Metropolitan Bus Model (MBM) is an existing model of this nature that could be used to assess different bus options. However, if more disaggregated outputs by service, area or ticket type is needed, then this type of model may not be suitable. Please refer to the Toolkit for more information on the MBM.

3.2.2 Regional highway and public transport model

Regional transport multi-modal models typically comprise highway and public transport models covering a city or region (based around a city). They are bespoke models that need to be developed for a specific purpose and scale, and there are several examples across England.

An LTA using this model would typically utilise a regional highway / public transport model (such as the West Midlands PRISM model) to test of the impacts and benefits of bus interventions on the network.

These models typically include functionality for assignment of trips to routes, mode-choice, and variation in trip-making in response to improved transport networks (or reductions in trips when networks are congested). Multi-modal models typically enable testing of impacts of changes to routes, bus priority and speed changes, impacts of crowding, and changes to fares.

Sources of data for public transport demand can often be difficult to obtain due to commercial issues (for operators), and validation / calibration is often challenging due to the relatively small proportion of public transport trips (compared to highway demand).

This type of model would allow impacts to be tested as follows:

- Changes to bus frequencies;
- Changes to bus routes;
- Changes to bus speeds; and
- Changes to car travel such as parking availability or price.

For further information on examples of regional transport models, please refer to the Toolkit.

3.2.3 Agent based modelling

Agent based models (ABMs) are simulations which treats travel demand on a holistic basis (rather than simple A to B journeys) as a collection of journeys by autonomous decision-making entities called agents. Whilst in traditional modelling demand is represented as an aggregate

where travellers are grouped, in ABMs, each agent is modelled separately. In the model each agent assesses their individual travel situation and makes a decision based on a set of pre-programmed rules, with each traveller having their own journey choice modelled separately.

ABMs can model highly complex systems allowing discrete models rather than continuous ones. They allow the researcher to develop rules from which behaviours emerge meaning, an in-depth understanding of existing travel patterns is not required. ABMs incorporate the inherent 'randomness' of travel (that is, journeys can often be ad-hoc and unplanned), whereas traditional models are deterministic which does account for individual behaviour choice. The flexibility of ABMs allows disruptive technologies to be modelled i.e. on-demand transport can be considered at an agent level, thus enabling more detail on the choices available to specific travellers.

ABMs are relatively costly to develop and there is presently limited standard guidance (although future standardisation of processes and calibration is likely in the near future). Hence, at present, development of ABMs are mainly to assess policy choices rather than to test individual schemes or measures.

For further information on examples of agent-based models, please refer to the Toolkit.

3.3 Techniques

3.3.1 Scenario testing

Scenario testing is a common method used for bus demand forecasting. It involves developing different scenarios to examine all possible future bus demand considering key cost and demand drivers, such as demographics, travel patterns, service improvements, fares and subsidy. By doing this, more accurate and robust forecasts can be developed to reflect the complex and dynamic nature of demand changes and to inform the general trend.

The baseline patronage is the main input of this method, which can be sourced from DfT data or local bus operators. The future patronage estimation will be built upon assumptions around these key drivers, with data sourced from local Bus Strategy Investment Plans (BSIPs), Office for National Statistics (ONS), DfT concessionary travel statistics and alike.

Historic growth rates from existing data or from DfT annual bus statistics at national level can also inform the forecasting outputs. However, it has limited capability to inform future demand upon unexpected disruptions, such as the COVID-19 pandemic.

The key targeted output is changes in patronage volumes into the future. Depending on the scenario analysed, fare or service mileage may also be the outputs.

This exercise can be carried out using Excel or DfT's ABOD service. ABOD forms part of the DfT's ongoing investment in bus services. There also are some models available in the market to be utilised, such as Metropolitan Bus Model (MBM)[4], which is an Excel-based model used in a study of bus subsidy impact in English metropolitan areas.[5] Further details can be found in section 3.3.1.3.

[4] Urban Transport Group, Metropolitan Bus Model. Available from https://www.urbantransportgroup.org/metropolitan-bus-model

[5] MVA Consultancy, Modelling Bus Subsidy in English Metropolitan Areas (2011). Available from https://www.urbantransportgroup.org/system/files/20110808ModellingBusSubsidyinEnglishMetropolitanAreasFinalReportAbridgedv50.pdf

3.3.1.1 Advantages

Scenario testing, as a popular method especially for bus patronage forecasting, has several advantages:

- It can test various scenarios and assumptions, enabling the examination of all possible outcomes, whether related to service performance, policy aspirations or other factors. This helps LTAs to anticipate and prepare for different circumstances in the future;
- New analyses can benefit from abundant existing examples as it is one of the most common methods adopted for the purpose of baseline analysis and forecasting;
- The concept is easy to understand and therefore estimations can be made quickly and efficiently; and
- Easy access open data for all parties can be utilised - sourced from Bus Open Data, ABOD service is available to bus operators, LTAs and relevant transport bodies including DfT, Driving and Vehicle Standards Agency (DVSA) and Office of Traffic Commissioners (OTC).

3.3.1.2 Disadvantages

While there are many advantages, it is also important to consider its constraints to inform whether it is the best approach for the given situation. Few disadvantages are listed below:

- Inaccurate assumptions can lead to inaccurate results as the method is heavily reliant on the assumptions;
- The methodology has limited capability to handle uncertainty or unexpected developments other than those captured in the study scenarios;
- Instead of providing detailed forecasting analyses, this method may be more appropriate for predicting trends given the simplifications of assumption-making process;
- There is technical constraint to use Excel for big data processing and therefore it may not be able to cover a large quantity of services or over a long period of study timeframe; and
- There aren't many examples where bus services have been forecasted at disaggregated level but tend to be aggregated data for the entire study area.

3.3.1.3 Case studies

Transport for London published bus use and supply data from 1999 to 2022 as an evidence base for the bus service for London Assembly Transport Committee report in 2013[6]. This technical analysis includes baseline demand comparisons, journey time by route, forecast demand analysis, subsidy, concession, and expenditure analyses. An annual population growth of 1.3% between 2011/12 and 2021/22 sourced from ONS population forecasts and a 7% increase between 2013/14 and 2021/22 were assumptions included in the forecast demand analysis.

Another study carried out by MVA Consultancy on bus subsidy impact in English metropolitan areas tested three scenarios covering concessionary travel entitlement age change, funds and grant cuts. A more complicated model was used to predict key indicators forecast in patronage, fares and service mileage. The three scenarios depicted the relationship between respective fare and subsidy changes, informed the trend towards rising fares and falling demands in the near future. However, it is important to consider current economic climate when examining the results.

[6] TfL, Bus Use and Supply Data 1999-2022 (2013). Available from https://data.london.gov.uk/dataset/bus-use-and-supply-data-1999-2022?resource=5836afbe-936d-4a46-9289-39ab0892f38d

3.3.2 Elasticity measures (spreadsheet and regional modelling)

Bus demand elasticities are commonly used to indicate the responsiveness of bus patronage to changes in other variables. Demand elasticity measures are essential for demand forecasting, investment decision-making, and policy development in the bus industry, and have been researched since the 1970s. DfT published a document reviewing bus elasticities and diversion factors in 2018, which provided evidence on key variables such as bus fare, bus journey time and diversion factors for all modes[7]. A comprehensive guide for the public transport demand published by TRL in 2004[8] also provided recommended elasticity values, detailed advice on model selection and application, and a dedicated software for this purpose.

Demand prediction in the foreseeable future can be informed by baseline patronage data and the elasticity values available from similar documents as mentioned above, either from the government or professional bodies. Alternatively, elasticity values that are unique to the study area can be derived from historical ridership, fare or journey time data. In addition, data for fares, journey time, service reliability, punctuality or waiting time helps to characterise the service of interest, further aids the selection of appropriate elasticities.

Excel is typically used for this exercise. To develop specific elasticity values, statistical software such as SPSS may well be required.

3.3.2.1 Advantages

Several advantages of elasticity measures have been identified, including:

- The method has been widely used, particularly in an economic context, which consequently provided sufficient examples for new studies;
- There is open source data of elasticity values provided by the government (DfT) or organisations alike;
- Certain qualitative factors can be included in the forecasts by being converted to generalised cost or generalised journey time. As such, impacts of soft measures can also be evaluated; and
- The method provides valuable insights to the relationship between the variables chosen and their respective impact on future patronage. This piece of information can be translated easily to stakeholders to develop relevant strategies.

3.3.2.2 Disadvantages

However, the method is not without limitations. Potential limitations include:

- It is not always suitable for long-term demand forecasting or decision-making in rapidly evolving environments. This is because the elasticities are based on historic data, which may not be appropriate to reflect future conditions if they are significantly different from the existing conditions which the values are based on;
- There is a need to validate the recommended elasticities before applications to ensure the values are representative for the case in question; and
- It can be difficult to include all potential factors, particularly the exogenous factors, resulting in an incomplete picture.

[7] DfT (prepared by RAND Europe and SYSTRA), Bus elasticities and diversion factors (2018). Available from https://www.gov.uk/government/publications/bus-elasticities-and-diversion-factors

[8] TRL, The demand for public transport: a practical guide (2004). Available from https://trl.co.uk/uploads/trl/documents/TRL593%20-%20The%20Demand%20for%20Public%20Transport.pdf

3.3.2.3 Case studies

The elasticity measures, or elasticity-based demand models as referred to in a bus soft factors study conducted by AECOM for DfT (2009)[9] , were the key models used for car and bus user demand analyses, among with other models including 'Unpacking' SP Models, Information SP Models, Mode Choice-Based Demand Models etc. This usage case demonstrates the benefits of considering soft measures using elasticity-based demand model. The table of soft measure elasticities in the executive summary gives clear indication of the scale of impact each measure could have, allowing readers to grasp the key messages quickly and easily.

3.3.3 Time series model

A time series model is a statistical model used to analyse data collected over a period, which is treated as a time series, to understand the dataset or predict future trends. The model often builds on historical data for forecasting, and therefore it best suits the short-term forecasting assuming travel patterns of the past are likely to continue in the near future. The first time series model developed was the linear autoregressive moving average model (ARIMA)[10].

Travel demand data is time series data in essence and it exhibits periodic patterns across the time of day or day of the week. Therefore, this approach of public transport demand modelling has been growing ever since. However, it is worth noting that the input data has to be indexed in time order. In this case, bus ticket data or smartcard data can be used in this model as it has it is timestamped but data aggregated across time may not be suitable.

Statistical analysis software is required for this exercise, such as Excel, EViews, SPSS.

3.3.3.1 Advantages

The advantages of time series models are as follows:

- Time series models have been used in a wide range of disciplines such as finance, retail and economics. Public transport demand modelling is just a small part of the method applications;
- This method requires data cleaning for accuracy, making it easy to assess the general patterns without going into too much detail; and
- Time-based assumptions can be tested easily with this model, such as increasing bus frequency at certain periods of time.

3.3.3.2 Disadvantages

However, there are certain disadvantages that shouldn't be overlooked when choosing the method for forecasting:

- Only a limited number of academic studies are available with case studies, but no practical user case has been found so far. This implies the method may be theoretical and need further validation should it be used widely;
- It may not be easy to obtain bus ticket data or smartcard data for all services from the operators as this is commercially sensitive. Surveys can be done to fill certain gaps but they can be costly given the amount of data needed to build a robust baseline; and
- As mentioned above, time series model has limited predictive power if drastic changes are to take place compared to the baseline.

[9] AECOM, The Role of Soft Measures in Influencing Patronage Growth and Modal Split in the Bus Market in England (2018). Available from https://cambridge.blob.core.windows.net/public/ldf/coredocs/RD-T-050.pdf

[10] George E. P. Box, Time series analysis, forecasting and control (1970)

3.3.3.3 Case studies

There are limited number of academic articles exploring the usage of time series data to forecast public transport demand e.g. in Istanbul[11]and bus passenger demand in particular in Spain[12] and Taiwan[13]. However, no study based in the UK has been found during this research.

3.4 Review of options

A summary of the advantages and disadvantages of each of the modelling options presented in Table 3.1 can be seen in Table 3.2. However, there are some concerns over revenue risk and viability from bus operators, resulting in a divergence between theory and practice from the forecasting analysis.

Table 3.2 Methods summary

Method	Advantages	Disadvantages	Development cost range & timescales
Non-assignment, spreadsheet based model	• Provides a simple way to assess some elements of bus strategy without the need for a full assignment model	• Limited functionality and unable to assess multiple elements of a scheme • Not suitable for assessing Mass Transit	Relatively cheap to develop <6 months to develop and implement
Regional highway and public transport models	• Good network coverage and representation of district / region • Can provide localised demand forecasts • Testing for demand model convergence (between the demand and the assignment) is straightforward	• Can have a lot of 'noise' • Some modes i.e. park and ride may be difficult to represent • Level of detail of network across the whole model may differ • Calibration could be complex	Moderate to high expense to develop 1-2 years to develop and implement
Agent based modelling	• More detailed modelling of traveller behaviour at the individual level • More detailed representation of interventions on decision making, including equity • Can assess mode shift across different modes • Can assess new technologies including autonomous vehicles and MaaS • Can be used for areas without buses in the baseline year • Modular development – early insights developing over time	• Emerging guidance within TAG that sets out how ABM models should be developed • Not suitable for Green Book business cases • Can require significant additional data	Cost varies but typically more expensive < 6 months for initial model but could be 1-2 years for more detailed model

[11]Emre Su and Ozum Asya Su, Public Transport Demand Forecast Using Arima: The Case of Istanbul, https://papers.ssrn.com/sol3/papers.cfm?abstract_id=4020644

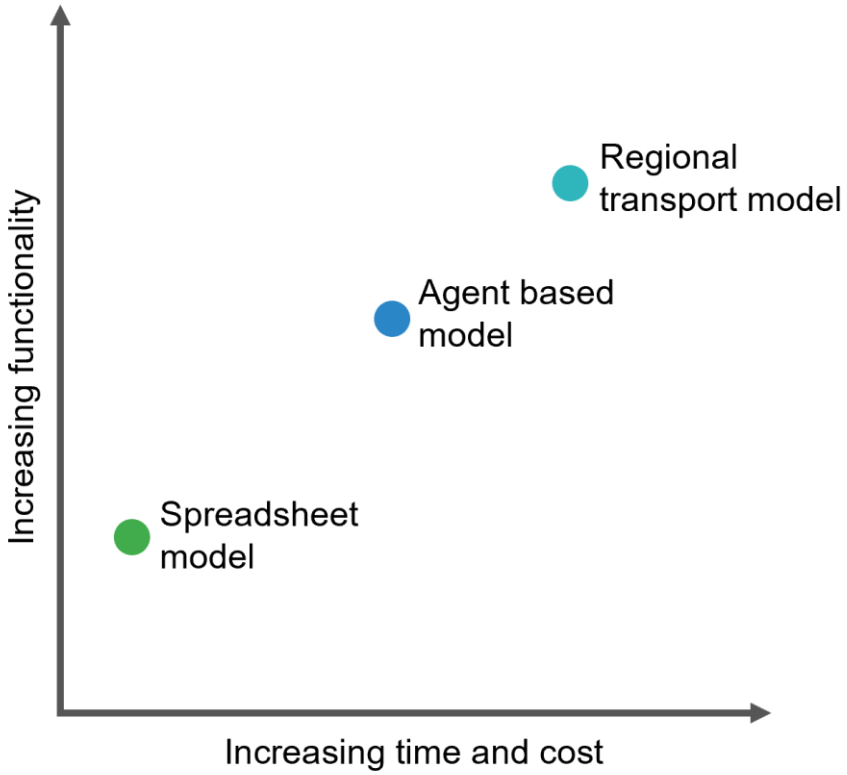
[12] Irene Mariñas-Collado et al. Clustering and Forecasting Urban Bus Passenger Demand with a Combination of Time Series Models, https://www.mdpi.com/2227-7390/10/15/2670

[13] Cheng, Ching-Hsue, Ming-Chi Tsai, and Yi-Chen Cheng, An Intelligent Time-Series Model for Forecasting Bus Passengers Based on Smartcard Data (2022), https://doi.org/10.3390/app12094763

3.5 Recommendation

The range of methods presented make it clear that no single option can be recommended. Models will be assured for a specific scheme and the appropriate model selected. Figure 3.1 highlights functionality over the time and cost to build the model.

Figure 3.1: Modelling functionality vs time and cost



4 Monitoring performance and performance indicators

Monitoring requires a regular assessment of a number of performance indicators based on a combination of data sources. This section provides an overview of metrics that will be used to measure goals and objectives for the operation of the local bus network. These metrics – Key Performance Indicators (KPIs) – will help set a performance baseline to which regular monitoring will be compared. Since one of the main objectives of improving bus performance is to attract more users, **patronage** (number of bus users), is a main key indicator. **Punctuality** and **passenger satisfaction**, the other two main KPIs, can help highlight areas where improvements could take place to make a bus service more attractive to existing and potential users.

The selection of performance indicators accounts for the basic principles that data should be easy to collect, require little or minimal calculation and that can highlight changes over time.

4.1 Key Performance Indicators

Patronage, punctuality and passenger satisfaction KPIs are further broken down into:

- **Patronage**
  - **Total passenger journeys**: The dataset is provided annually by DfT and is disaggregated down to local authority level and can help highlight aggregate increase or decreases in bus ridership.
  - **Passenger journeys per head of population**: This metric is a supporting indicator that can help isolate journeys from fluctuations in population growth (2021 Census and updates). The patronage dataset is provided annually by DfT and is disaggregated down to local authority level.
- **Punctuality**
  - **On-time performance:** ABOD metric outlining the percentage of buses arriving to their stops on time (<1 minute early, >5 minutes late) for a local authority. This metric can also drill down to corridor- and stop-levels for spot checks e.g. peak period punctuality compared with offpeak or the relative performance of individual routes.
  - **Bus speed as a proportion of general traffic speed**: This metric is a supporting indicator that can help identify the efficiency gap between the car and the bus service as well as indicate where interventions may help reduce bus journey times. An alternative measurement for specific corridors or points is to take peak hour speeds and late evening speeds where free flowing traffic is expected.
- **Passenger satisfaction**
  - **Overall satisfaction**: This summary metric includes information gathered by Transport Focus during personal interviews at bus stops on the following topics:
    - Journey time;
    - Punctuality;
    - Value for money;
    - Bus driver greeting/welcome;
    - Interior cleanliness and condition; and
    - Availability of seating or space to stand.

Transport Focus' bus passenger surveys were cancelled for 2020 and 2021. Consequently, the most recent survey available is for 2019 until the upcoming release of 2022 results. The surveys take place on a cyclical basis so data may not always be as up to date as will be required.

- **Journey time satisfaction:** Transport Focus' annual survey includes satisfaction with journey time, which can highlight users' perceptions of the efficiency of travel and can be compared with actual performance data described by punctuality data. This is a supporting indicator.
- **Value for money:** This supporting indicator can inform objectives relating to ticketing and fares and can help identify patterns after the implementation of ticketing schemes. It can also highlight where positive perceptions could be translated to other routes, noting that poor value for money may be related to rapid journey times.

Table 4.1: Methods of data collection for different KPIs

Key performance indicator group	Indicator	Method
Patronage	Passenger Journeys per head of population	Measuring passenger numbers through DfT's Local Bus Passenger Journeys Dataset BUS01f
	Total Passenger Journeys	Measuring passenger numbers through DfT's Local Bus Passenger Journeys Dataset BUS01e
Punctuality	Bus Speed as a Proportion of General Traffic Speed	Analysis of ABOD Bus Speeds at sample locations against DfT's general traffic speeds measurements CGN0503. If Automatic Traffic Counter data is available for important locations as
	On-Time Performance	Measurement of punctuality from Analyse Bus Open Data
Passenger Satisfaction	Overall Satisfaction	Feedback from satisfaction surveys from the Transport Focus Data Hub
	Satisfaction with Journey Time	Feedback from satisfaction surveys from Transport Focus. Metric can also be broken down for commuter/non-commuter.
	Satisfaction with Value for Money	Feedback from satisfaction surveys from Transport Focus. Metric can also be broken down for commuter/non-commuter.

4.2 Monitoring Performance

All the above KPIs should be assessed to identify issues and opportunities to set a baseline for later evaluation. The KPIs can also be supplemented with operator data, such as patronage figures and passenger satisfaction if available.

4.2.1 Monitoring areas

KPIs should be gathered for the local authority as a whole. General speed data from DfT can also be supplemented with spot checks from permanent ATCs gathering speed data, as ABOD can provide comparison bus speeds at single locations. On-time performance data can also be easily collected for select corridors, origins, or destinations through ABOD.

4.2.2 Monitoring timeframes

Monitoring should be regular, with a minimum annual assessment. For metrics that allow for monthly monitoring such as punctuality or data acquired from operators, a sample should be taken for a neutral month such as April, May, June, September, or October. For Passenger

surveys, the sample size should encompass over 75 respondents to align with the Transport Focus methodology.

5 Evaluation

Evaluation must be carried out after implementation to allow improved management and adaptations, leading to more effective operational delivery. It can also be used post-implementation to assess the value of intervention, gain insights into customer needs and summarise lessons learnt throughout delivery. This section outlines the evaluation principles and methods of bus data interventions.

Evaluation to assess and manage the intervention success is important as it:[14]

- facilitates transparency, accountability and development of the evidence base;
- can be used to improve current interventions; and
- expands learning of 'what works and why' to inform the design and planning of future interventions.

There are several evaluation guidance documents available in the UK. DfT published TAG Unit E-1 evaluation in November 2022, which outlines best practices for planning the evaluation of transport interventions to ensure robust evidence collection to reflect the impacts of interventions in reality[15]. It is suggested that this is read in conjunction with the Treasury's Magenta Book[16], which provides guidance on evaluation for government policymakers and analysts, and the Green Book, which focuses on appraisal, with some advice on monitoring and evaluation.

Furthermore, National Highways produces 'Post-Opening Project Evaluations' (POPEs) in the years following the completion of new roadbuilding projects (National Highways, 2022). The detail may be more than is needed for bus schemes: comparisons of overall traffic levels, bus journey time reliability and bus ridership figures, from before and after a few years, should suffice, but nevertheless some form of post-opening assessment should always be carried out, and ideally made publicly available.

General principles of a high-quality evaluation include:

- Useful, credible, robust and proportionate as described in the Magenta Book;
- Clear objectives to guide data collection and analysis;
- Develop indicators to assess the intervention outcomes; and
- Conduct the evaluation in a timely manner, which could be embedded in the delivery programme.

A summary of different evaluation methodologies for different bus infrastructure and service intervention types is presented in Table 5.1 below.

[14] HM Treasury, The Green Book, 2022, https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1063330/Green_Book_2022.pdf

[15] DfT, TAG unit E-1 evaluation, 2022, https://www.gov.uk/government/publications/tag-unit-e-1-evaluation

[16] HM Treasury, Magenta Book, 2020, https://www.gov.uk/government/publications/the-magenta-book

Table 5.1 Evaluation method and intervention types

Intervention	Method	Data required	Description	Evidence base
Concession (Money)	Cost benefit analysis	• Costs of delivery compared to benefits • Value for money • Ticket sales	Estimates the costs to government as well as the benefits the policy brings to both its users and society, and we generate a benefit cost ratio (BCR) for the scheme	See paper: evaluation-of-concessionary-bus-travel
Service performance	Patronage data	• Patronage data • Bus speeds • Collision data • Journey times / delays	Evaluate the service performance achieved as part of the intervention	See TAG guidance
Customer experience	Customer satisfactory survey (CSS) score -> social media discourse analysis	• Journey time • Waiting time • Driver behaviour • Journey smoothness, safety, • Comfort (riding, boarding and alighting), cleanliness, • Bus stop condition etc • Complaints	Evaluate customer experience and potential for mode shift / increased patronage. • TfL wants to develop a set of CSS metrics that capture the holistic customer experience of the bus, and will use this qualitative research to feed into the bus CSS development process • Complaints: For examples TfL's London Buses Customer Services department responds to thousands of service suggestions and complaints from passengers every week. The details of all complaints are recorded and actioned.	https://content.tfl.gov.uk/exploring-the-bus-css-metrics.pdf

Intervention	Method	Data required	Description	Evidence base
Modal shift	Customer satisfaction survey (CSS) score -> social media discourse analysis	• Travel mode • FMLM travel mode • Alternative travel mode • Usage frequency • Journey purpose	Evaluate the mode shift achieved from the measures implemented. This can then be used to evaluate carbon and air quality impact (as discussed below).	
Zero emission	Customer satisfaction survey (CSS) score Spreadsheet analysis	• Emissions factors • Mode shift proportions •	The evaluation approach is currently being finalised but will include programme-level monitoring of outputs, outcomes, and costs, including data to inform analysis of carbon impacts, and process evaluation interviews with local transport authorities, bus operators, and other involved parties.	Monitoring and evaluation of the Zero Emission Bus Regional Areas scheme https://www.gov.uk/government/publications/dft-monitoring-and-evaluation-programme/dft-evaluation-strategy-and-programme-2022