

The future of the bus vehicle market in Scotland

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1 Executive summary

Zero-emission buses – particularly battery electric buses – will soon become standard for the vast majority of new mainstream local buses operating in Scotland. This will contribute to Scotland's ambitious climate target of net zero by 2045. However, it is unclear what the second-hand bus market will look like for battery electric buses and what impact any resulting changes to the market will have on operators and the places and communities they serve.

This study explored what a move to battery electric buses (BEB) might mean for the future second-hand bus market in Scotland. To do this, we:

- defined the current structure and business models used within the second-hand bus market in Scotland;
- assessed future market dynamics and the impact the transition to BEBs might have on operators; and,
- discussed different ways of managing the transition with government and stakeholders.

Although this study set out to understand the second-hand bus market, the study soon found that:

- smaller bus operators are just as likely to buy new buses as the big operators; and,
- big operators may start new buses on city routes, however their intensity of use means it is more difficult to deploy BEBs on these routes (requiring greater daily range) than many rural routes.

These findings resulted in the study taking a broader view of the impact of battery electric buses across new and used use cases and big and small operators.

The current market

We found that the current market displays the following features:

- **The sale of new buses in the UK and Ireland has been in decline for over a decade**, possibly driven by increasing risk and falling industry confidence. This

means that even without the introduction of BEBs, the structure of the second-hand market will change due to reduced supply and increased prices.

- **SME (small and medium-sized enterprise) local bus operators (here defined as operating 85 buses or fewer) are just as likely to invest in new buses as the larger bus operating groups.** The movement of buses within the second-hand market is not strongly influenced by an operator's size. This finding was contrary to commonly-held perspectives about the bus industry as a whole – that large operators buy new buses, the rest largely purchase second hand.
- **Buses transition from routes which make more money to routes which make less money over their life.** The value or sale price of a bus drops with each year of its life. To remain profitable, bus operators must run buses on routes with a high earning potential in their early life but can work on lower value routes as the bus gets older.
- **The definition of a high-earning route is different for different sizes of bus operator.** Many big bus operators operate frequent city centre routes, which are generally high earning routes. They may also deploy their best buses where there is on-road competition for passengers. They may therefore start buses here and move them to more rural routes over time. Small bus operators are less likely to be able to compete on such routes but instead build their core business in market niches, such as more rural places.

Challenges and solutions in the new bus market

We found that the main challenges for introducing BEBs in the new bus market are:

- **Limitations in driving range.** Our analysis showed that high frequency routes, which have the greatest daily energy requirement, are amongst the hardest for BEBs to serve. As these routes tend to make the most money for bus operators, these routes are where new buses have traditionally been placed. This means that, contrary to initial expectations, it is the big groups' new buses, not the second-hand bus market, where the greatest initial challenges will exist for BEBs.
- **The high cost of battery electric buses and the uncertainty around the lifetime of the battery.** BEBs are significantly more expensive than diesel buses. This additional up-front cost poses another risk for bus operators who are already facing uncertainties about their future. We see a reduced appetite to buy new diesel buses, let alone BEBs. This risk is made worse by uncertainty around how long batteries will last in operation. Batteries have been shown to last far better than expected but there is still a lack of data about battery condition after 10-15 years, when groups might sell the bus on for the first time.

To overcome these challenges, we think operators of new buses could take the following steps:

- **Delay investment until buses with bigger battery size are available.** For most routes, it is feasible that manufacturer improvements will deliver enough battery capacity in the next 10 years. However, longer distance routes (more than 20 km each way), such as those that link cities with surrounding areas, will still struggle.
- **Use buses with smaller battery sizes but rely on opportunity charging.** This approach is likely to be most feasible for routes that cross or enter cities. However, there are disadvantages in cost and battery life to this approach. Not all routes will have the operational flexibility or infrastructure to do this.
- **Put new battery electric buses only on shorter and/or less frequent routes,** which are easier to electrify. However, only a proportion of routes are compatible.
- **Deploy hydrogen fuel cell electric buses** (out of scope for this study).

- **Consider new business models** where batteries are leased to bus operators. This is very widely used as it helps to bring down the up-front cost of these vehicles and transfers risk around battery life to the leasing company. As batteries degrade, new batteries will be placed in buses and old batteries will be moved out to second life applications.

Implications for the future second-hand bus market

No one strategy will be effective for everyone and a mix of the above approaches is likely. If the above approaches are taken in the first-hand bus market the potential implications for the second-hand bus market are:

- **Decreased supply** of second-hand buses as new bus investment is delayed.
- **A trend towards buses with very large batteries**, which are over specified for the needs of many second-hand bus operations and are therefore more expensive than necessary.
- **Reliance on opportunity charging**, which might only be feasible where many bus routes come together. This may leave long-distance “interurban” routes without an immediate battery bus solution.
- **Leased battery models could reduce bus lifetime or increase bus costs in later life.** This trend presents the greatest uncertainty for the second-hand market as separating the bus body and the battery completely changes the dynamics of depreciation. The implications for the second-hand market include:
 - **Putting new batteries in an old bus will mean that the overall cost of buses will not decrease as they age.** In effect, second-hand bus owners will need to pay battery leasing prices that are close to that of a new bus.
 - **Batteries will be drawn out of the bus market when their value in other markets exceeds their value in buses.** This could mean that there are no older batteries commercially available for use in old buses. This effectively would put a firm cap on the maximum age of a bus. Existing end-of-life users, including many home-to-school contractors, may need to evolve their operations towards younger buses.

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Glossary and abbreviations

Term	Definition
BaaS	Battery as a service – a battery leasing model, described in 0.
BEB	Battery electric bus.
BESS	Battery energy storage systems, where batteries are used in energy trading and grid services.
Bus	Defined by this study as a vehicle which has routinely operated a registered local bus service in Scotland at some point in its life, regardless of body type (see “What is a bus” at the end of chapter 2). This may be presumed a vehicle with at least nine seats excluding driver.
Bus-bodied	Specifically refers to a vehicle with a bus-style body and typically a capacity for at least 22 passengers (standing or seated), although PSV Circle records do sometimes classify smaller vehicles as buses.
Coach	A coach-bodied vehicle, normally licenced to convey only seated passengers, and typically with at least 22 seats, although PSV Circle records do sometimes classify smaller vehicles as coaches.
Dealer	A third-party reseller, leaser, or sometimes scrapper of buses (further defined in 0).
Depot	The day-to-day operating base for buses.
DfT	United Kingdom Department for Transport.
Dominance	Local market share relative to all other direct competitors, where 100% is an absolute monopoly (detailed in 0).
DVLA	Driver and Vehicle Standards Agency.
End-of-life	Low-duty intensity roles after leaving mainstream local bus service operation, typically school contracts, events, or rail replacement.
Group	Local bus operating group made up of two or more individual local operating companies. All groups operating in Scotland are non-SME (see “What are large and small bus operators” at the end of chapter 2).
GTFS	General transit feed specification, the standard interchange format for public transport schedule open data.
km	Kilometres. Vehicle “mileage” is also calculated in kilometres.
kWh	Kilowatt hour, here as a measure of battery capacity.
Large SME local bus operator	A non-group operator providing at least 50 vehicle trips daily. This criterion emphasises SMEs that are primarily local bus operators.
Licence discs	The maximum number of PSV vehicles an operator is legally permitted to operate.

Local bus service	A scheduled road passenger service that has been registered with the relevant Traffic Commissioner and is contained in the Traveline Scotland dataset. This includes scheduled longer distance routes wholly within Scotland.
Move	A permanent change in a bus's operator, normally including a change of geographic location.
MWh	Megawatt hour, here as a measure of battery capacity.
NaPTAN	National public transport access nodes, a national database of bus stops and similar.
NOC	Traveline national operator code, which identifies local bus service operators uniquely by trading name.
OEM	Original equipment manufacturer.
Operator	Without explicit context, the trading-named operator of local bus services. Trading names may combine one or more different registered company names.
PSV	Public service vehicle (see "What is a bus" at the end of chapter 2).
PSV Circle	Bus enthusiast organisation.
Urbanity	Rural-urban index as a percentage, where 100% is most urban (detailed in 0).
Vehicle	A unique PSV chassis, which will typically retain the same body throughout its life, but not necessarily to the same registration.
Vehicle trip	Count of out-or-back scheduled end-to-end bus vehicle trips, typically expressed per average day or weekday.
Registration	The alpha-numeric legal identification plates attached to each vehicle. Re-registration refers to switching one set of a plates for another.
Route	Uniquely numbered and operated bus route, typically serving a collection of often-repeated bus stops. Route variation refers to a specific sequence of bus stops. Routes typically consist of two or more route variations.
ScotZEB	Scottish zero emission bus challenge fund (a vehicle grant).
SME	Small and medium-sized enterprise, within Scottish local bus operation, not a group (see "What are large and small bus operators" at the end of chapter 2).
SULEBS	Scottish ultra low emission bus scheme (grant funding).

2 Introduction

2.1 Context

The Scottish Government has set some of the most ambitious climate change targets of any nation in the world. These targets require emissions to reduce by 75%, 90% and 100% (net zero) compared to 1990 levels by 2030, 2040 and 2045, respectively. Achieving these targets will require both rapid technology shift and significant behaviour change among businesses and the public.

The transport sector has historically proved one of the more challenging to decarbonise, with emissions remaining relatively stable since 1990. Local buses are a key policy tool in reducing emissions from transport. Zero emission buses¹ – most likely battery electric buses (BEBs) – will need to become standard for the vast majority of new mainstream local buses operating in Scotland. As the shift to accessible (typically low-floor) buses since 1995 has demonstrated, fleets transition at a steady pace that cannot be readily accelerated by policymakers.

Larger bus operating groups tend to be at the forefront of fleet decarbonisation, small and medium-sized enterprise (SMEs, defined in the box “What are large and small bus operators”, below) operators struggle technically and financially to invest in zero emission buses. The supply and price of second-hand buses has historically influenced the viability of many local bus operations affecting large and SME operators in different ways. However, it is unclear whether a second-hand market for battery electric buses will even exist. There could be significant impacts on operators that have historically relied on the second-hand market, and thus on the places and communities those operators serve.

This study aims to understand how a swift transition to zero-emission buses amongst large operators will impact the second-hand bus market, and what the implications are for SME operators. The study considers options for mitigating any negative implications in the context of a just transition.²

2.2 Objectives, scope and approach

Our research method aims to understand the impact on operators of the transition to battery electric buses through:

1. **Analysis of current market structure:** Understanding how the second-hand bus market currently functions, to establish underlying motivations and dynamics.
2. **Assessment of likely future market dynamics:** Identifying the challenges that battery electric buses bring through: assessing the capabilities of new BEBs, the transferability of BEBs between different roles, and the scope for mitigation through alternative delivery models.
3. **Framing the role of government and wider stakeholders:** Identifying ways that the bus market can be supported to avoid negative impacts on operators, especially SMEs.

¹ Zero emission vehicles are those that have zero emissions at tailpipe. These include battery electric vehicles and hydrogen fuel cell vehicles.

² A just transition is defined in law as action to reduce net Scottish emissions of greenhouse gases in a way which: supports environmentally and socially sustainable jobs, supports low-carbon investment and infrastructure, develops and maintains social consensus, creates decent, fair and high-value work in a way which does not negatively affect the current workforce and overall economy, contributes to resource efficient and sustainable economic approaches.

The study focuses on buses, which are defined in this study as vehicles that have routinely operated registered local bus services in Scotland at some point in their life, regardless of vehicle body type (see box “What is a bus”, below). Vehicles used only in other parts of the bus and coach industry (coach tours, private contracts) are considered only in so far as they can be substitutes for buses or affect the decisions of smaller operators with mixed business models. For example, a school contract operator may be able to use coach and bus-bodied vehicles interchangeably, so if there is a shortage of second-hand buses, they may source ex-coach tour vehicles instead.

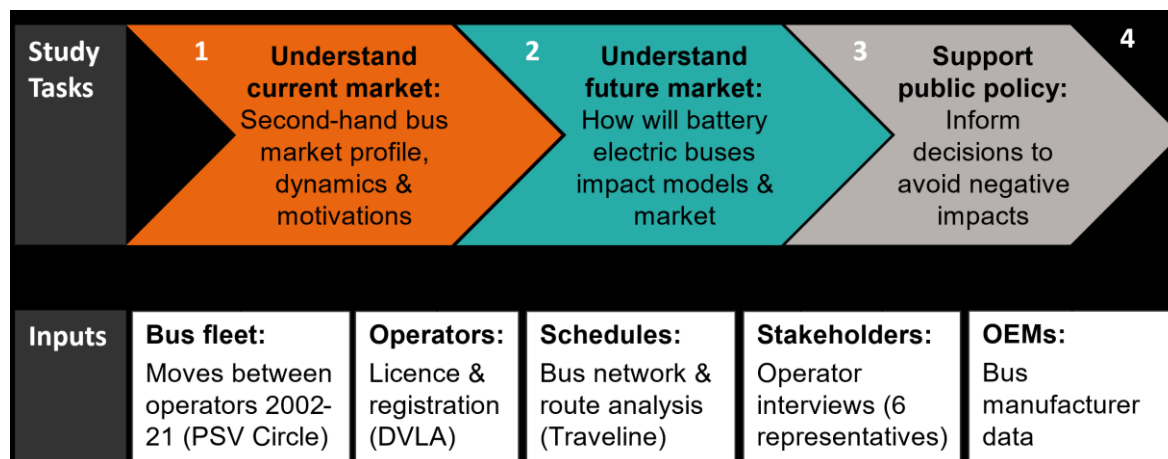


Figure 1: Overview of approach³

Our approach is summarised in Figure 1, above. We compiled data on historical bus movements between operators over the last two decades, to analyse second-hand bus market dynamics. We translated bus schedules into a route-level model to strategically assess the compatibility of battery electric buses with current operations. We conducted interviews with six industry representatives to understand their motivations and likely reactions to future decarbonisation scenarios. Detailed methods are provided in the appendices (chapter 6).

2.3 Structure of the report

Chapter 3 sets out our understanding of the current market and business models. Chapter 4 examines challenges of the transition to electric buses and the specific impacts that can have on smaller operators. Chapter 5 summarises our conclusions. The appendix, chapter 6, details our methods and sources.

What is a bus?

A bus is defined by this study as a vehicle which has routinely operated a registered local bus service in Scotland at some point in its life. This definition reflects the initial aim of the study: To understand the impact of the move to battery electric buses by large operators – a transition currently almost entirely limited to vehicles used on local bus services.

A local bus service is any road passenger service registered with the relevant Traffic Commissioner, which includes scheduled longer-distance routes wholly within Scotland.

³ The PSV Circle data is the leading enthusiast source of bus fleet data. The Department for Transport’s Driver and Vehicle Licensing Agency is the best official source. Traveline is the partnership that manages local bus schedule open data. OEM refers to the original equipment manufacturer. Input sources are further described in chapter 6.

This service-based definition includes routes operated using coach or minibus bodied vehicles. Coach-bodied vehicles can be important to Scottish local bus operation on interurban and longer rural routes. For example, 30% of vehicles new to Stagecoach's Scottish operating companies over the last 20 years have been coach-bodied. Minibus operation of local bus services is now extremely rare and almost entirely restricted to the smallest operators.

Vehicles used on local bus services are a subset of public service vehicles (PSV). PSV also includes vehicles used for non-scheduled group tours and private contract work. There is no legal distinction: Any PSV vehicle *could* be used on a local bus service. Further, vehicles are assigned to operating companies, not to specific services.

Large operators focus overwhelmingly on operating local bus services, so their fleets have a corresponding tendency to be buses as defined by this study. In contrast, the smallest operators are more likely to mix business models – typically combining any local bus work with private contracts or group hire. This can make it more difficult to separate bus vehicles from other PSV roles within the smallest operators.

What are large and small bus operators?

A small or medium sized enterprise (SME) is defined⁴ as a company with under 250 employees with less than €50 million turnover or €42 million balance sheet. Stagecoach's British bus business, which is the largest in Great Britain, averages about three employees per bus with about £140,000 of annual revenue per bus⁵. Assuming Stagecoach as a proxy for the industry, a local bus service-operating SME is defined based on employees, where fewer than 250 staff equates to fewer than 85 buses.

This definition of an SME almost perfectly mirrors the split between a bus operating group and an independent bus operator. So, the only large Scottish bus operating enterprises are groups, namely: Craig (West Coast Motors), First, Lothian, McGill⁶, Parks (of Hamilton) and Stagecoach. These groups collectively provide 88% of all local bus vehicle trips in Scotland, where a vehicle trip is defined as a one-way end-to-end bus vehicle trip. They collectively maintain an active fleet of about 3,800 buses⁷, equating to an average of 11 daily vehicle trips per bus.

SMEs provide the remaining 12% of all vehicle trips, drawing from a fleet of about 2,100 PSV vehicles – the equivalent of less than three daily vehicle trips per vehicle. SME-operated routes are slightly shorter in length on average (17 kilometres vs 19 overall). The apparent difference in the efficiency of vehicle use between SMEs and groups often reflects the tendency for SME operators of local bus services to be *primarily* engaged in other PSV roles, such as group hire or non-local bus service contracts.

⁴ SME definition, European Commission, https://single-market-economy.ec.europa.eu/smes/sme-definition_en

⁵ Calculated from Stagecoach Group Annual Report and Financial Statements 2022, https://www.stagecoachgroup.com/~/_media/Files/S/Stagecoach-Group/Attachments/financial/agm/annual-report-2022.pdf

⁶ Analysis of McGill includes the former operations of Arriva Scotland West and Travel Dundee, but not First Scotland East (Central), which transferred ownership while this study was being prepared.

⁷ Assumes 70% of vehicle operator licences are in use on local bus services. This proportion was derived, for a sample of operators, by comparison of Vehicle & Operator Services Agency licence data with 2022 enthusiast fleet lists, validated using bus open data (BODS) automatic vehicle location tracking. The Covid pandemic reduced service levels and active fleet requirements. Operators may reasonably be expected to retain sufficient licences to recover, so the 70% is factor is likely to be an underestimate of the long-term balance.

82% of the SME vehicle trip total is provided by just a third of all the SME operators. These are analysed as major SME operators, defined as providing at least 50 vehicle trips each weekday. The remainder of SMEs are considered minor. Our distinction between major and minor is not perfect, but it broadly indicates the likelihood of either being, or not being, primarily engaged in local bus service operation.

3 Understanding the current market

This chapter describes the workings of the existing second-hand bus market, with focus on buses with history as a Scottish operator. It primarily does this by analysing almost every bus move between operators (every permanent change of operating company over the life of each vehicle) over the last 20 years, a method described and validated by section 6.1. Insight into operators' decision-making process (gained from operator interviews) sets this fleet-level analysis in context.

3.1 Why the second-hand bus market exists

This section introduces the second-hand bus market from a non-analytical perspective. The key findings of this section are:

- The second-hand market for buses is defined as the movement, not specifically the resale, of buses between operating companies.
- Operators transition buses from high to lower revenue-earning duties with age, while finding a balance between fleet standardisation and localisation.
- Risk, and its management within business accountancy, shapes bus investment decisions, and is especially apparent in SME decision-making.
- Every bus has a life story, and by aggregating the stories of almost every bus in the British and Irish fleet over the last 20 years, we will describe patterns of movement across the market.

Defining the second-hand bus market

Newly built buses rarely spend their entire career with one operator. On historical average, a bus can expect to work for three to four different operating companies during its life (as detailed in 0). The working life of a diesel bus is typically 15 years in mainstream local bus service operation. This is potentially followed by low duty intensity end-of-life roles, such as school contracts. These roles typically last another five years, with progressively fewer buses continuing to work through their twenties. Almost no bus survives beyond age 30.

Career moves may include those between different operating companies within the same group. Groups dominate the Scottish bus market, so these intra-group moves can be as important to market dynamics as moves between unrelated entities.

The requirement for right-hand drive buses largely segments Britain and Ireland from the wider European and global bus vehicle markets. Historically, the exceptions tend to be rare, for example the import of ex-Hong Kong buses that had originally been built to British standards but provided greater passenger capacity than buses available second-hand within Britain.⁸ Bus-bodied vehicles are primarily deployed on local bus services, as attested by the two thirds of all bus-bodied vehicles in Britain and Ireland that have history with a local bus operating group.

⁸ Second-hand Hong Kong tri-axle buses imported to the United Kingdom, Wikipedia, https://commons.wikimedia.org/wiki/Second-hand_Hong_Kong_tri-axle_buses_imported_to_the_United_Kingdom

Such a narrowly constrained market is easiest to understand through the interaction of demand and supply for buses, rather than as the monetary trading of buses. The second-hand market for buses is thus defined as the movement of buses between operating companies (and any other owner), not specifically the reselling of buses.

Operators' motivations and strategies

Operators tend to express their motivations in financial terms – both monetary and risk.

Moving a bus between operators, even within a group, is suboptimal. In addition to the cost and time of finding a new home, when the bus arrives, “engineering won’t trust it and commercial will want to spend money repainting it”, as one interviewee expressed it.

A new bus is a significant long-term investment for any operating business: An asset valued in the order of £200,000 that needs to be depreciated over about 15 years. British local bus operation is a low-margin business, which makes such investments quite risky. The recently rapid pace of bus technology change (initially the evolution of European engine emission standards⁹ every four or five years, now decarbonisation) complicates operators’ risk calculations further, by increasing uncertainty of future residual values.

Local bus operators are typically 90-95% commercial, meaning across 90-95% of their operations they are free to determine the services they offer. Operators are thus heavily reliant on passenger revenue from the farebox. Just over half¹⁰ of this revenue is paid by passengers through fares, with much of the remainder flowing from government, through Scotland’s national concessionary travel scheme which pays cardholders’ fares at an agreed percentage rate. Public support does not explicitly define the services operated, as it would for local authority contracted bus services, so revenue from fares continues to closely relate to commercial passenger markets. Hence the use of the term commercial.

The dominance of revenue from fares means that the underlying structural driver of the second-hand market is different in passenger markets. The characteristics of some local passenger markets mean they can sustain higher revenue earnings per bus than others. This pattern is explored further in 0.

From an accountancy perspective – especially a group accountancy perspective – a recently new bus needs to be used intensively to justify its currently high residual value. The bus thus needs to be assigned to an operation that has a passenger market that can support such intensive operation. Otherwise, a new bus diminishes, rather than enhances, the strength of that business’s balance sheet.

⁹ European emission standards, Wikipedia, https://en.wikipedia.org/wiki/European_emission_standards

¹⁰ Bus and Coach Travel, Scottish Transport Statistics, 2019, <https://www.transport.gov.scot/publication/scottish-transport-statistics-no-38-2019-edition/chapter-2-bus-and-coach-travel/>

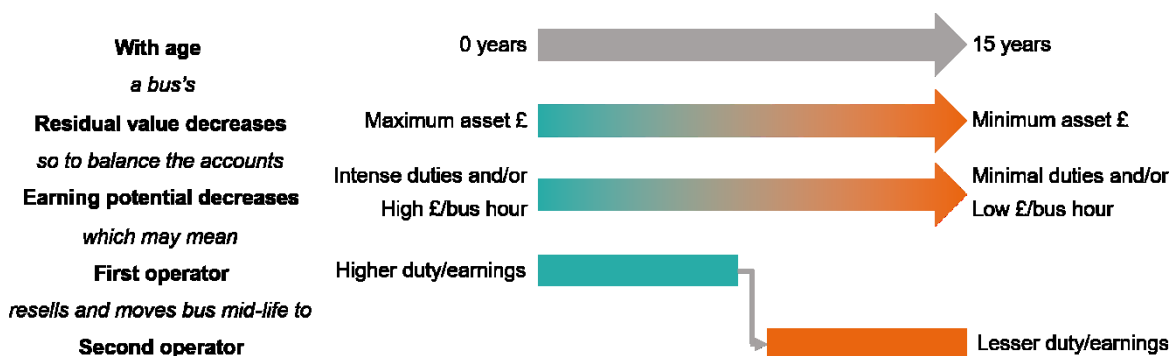


Figure 2: How balancing residual value to earning potential might affect the second-hand bus market

In practice operators will also consider a multitude of other factors when deciding where to deploy buses of different ages. Examples include whether staff maintenance experience matches a bus's make or model, local partnership opportunities and priorities, how well a bus's mechanical engineering or size matches the operational characteristics of envisaged routes, and the scope for a new bus product to generate new customers.

But the guiding pattern is of buses transitioning from high to lower revenue-earning potential duties as they age. Optimising that transition over time is as much a part of a commercially successful local bus business as the day-to-day operation of bus services. All operators need to marry operational fleet requirements with long-term financial strategy – even if that strategy just means out-sourced risk through leasing.

Operators' fleets are further influenced by a perpetual tension between the aims of standardisation and localisation: Standardised fleets offer maintenance economies of scale in staff training, parts supply, and manufacturer relationship. Localisation acknowledges that places differ, both in passenger market and route-level operation, something a generic fleet cannot always accommodate. The nature of the balance varies by operator.

So, successful local bus operators need to transition buses from high to lower revenue-earning duties with age, while finding a balance between fleet standardisation and localisation.

SME investment challenges

SME local bus operations, by dint of size, tend to operate less diverse networks. They are therefore less likely to be able to manage a given bus throughout its life, so are more dependent than groups on the open resale second-hand market.

This dependence on the second-hand resale market does not influence SMEs' propensity to buy new buses. As demonstrated in 0, SME local bus operators are just as likely as groups to acquire buses new. It does influence how SMEs manage the declining residual value of any bus they buy, because SMEs are more likely than groups to have to sell a bus into the open market during its working life.

SME operators that acquire new buses need to deploy strategies to manage the risk of their initial investment – both against its residual value when sold into the second-hand market, and the risk of an unforeseen but expensive mechanical failure.

Leasing can be attractive for new entrants to the bus sector, whose balance sheet could be unbalanced by up-front capital expenditure. Established operators, with mature revenue streams, are more likely to own buses – outright, or through hire purchase. The proceeds from the resale of older (but not yet mostly depreciated) buses will be used to

part-fund their new replacements, so maintaining adequate residual value is critical to being able to reinvest and sustain the business long-term.

Manufacturer warranties are one strategy by which the risk of new buses can be moderated: They effectively insure the operator against major unforeseen maintenance costs in the first three or five years of a bus's life.

For SMEs operating buses at or near end-of-life, the risk equation shifts from outright purchase cost (which is low for a largely depreciated asset) to the uncertainty of the remaining lifespan. Such buses might be kept running until an expensive mechanical component breaks, such as an engine or drive shaft, or the bus is simply no longer assessed to be road worthy. Interviewee commentary suggests the modern tendency is for bodies, not mechanical engineering, to fail with age.

While risk is a key factor across the local bus sector, it is perhaps most apparent for SME operators, who cannot fall back on institutional investors.

3.2 Scotland within Britain and Ireland

This section identifies patterns of new bus build and inter-operator movement across the entire British and Irish fleet. These raise issues pertinent to Scotland which Scotland has little influence over. Key findings:

- Scotland is integral to a wider British and Irish market. Only a third of buses new to Scotland can expect to spend their entire life in Scotland.
- But Scotland could sustain an internally balanced second-hand market, potentially allowing Scotland to pursue alternative fleet policies.
- New bus deliveries have declined since 2010, and dramatically so after 2016, constraining future market supply, regardless of electrification.
- The second-hand market will be less certain in the coming decade than in the past, which adds risk, which reduces investment, which exacerbates supply-side constraints.

Scotland is interdependent, but could be internally balanced

Buses in Scotland are technically identical to those elsewhere in Great Britain and the island of Ireland: Scotland is integral to a wider British and Irish market. But her imports and exports of buses are net balanced. So, Scotland could sustain an internally balanced second-hand market, potentially allowing Scotland to pursue alternative fleet policies.

While buses are effectively interchangeable within the British and Irish fleet, there are small skews in fleet profile between nations. Notably Scottish operators are more likely to favour coach bodies for local bus operation: In Scotland 17% of the fleet, across all groups, is coach bodied. The equivalent proportion for the whole of Britain and Ireland is 12%.

Overall, the requirement for right-hand drive vehicles frames the second-hand market within Britain and Ireland: As the figure below shows, less than 0.5% of buses with history at a Scottish local bus operator can expect to spend any of their career overseas. In contrast, almost two thirds can expect to also work in England.

The overall flow of buses balances out as roughly:

- third new in Scotland and later goes elsewhere
- third new elsewhere and later goes to Scotland
- third new in Scotland and remains

There are benefits to being able to move buses in and out of Scotland. For example, the far greater number of potential origin or destination operators makes the second-hand market more fluid and flexible when attempting to find a new home for a bus. Likewise, it is intuitive for First and Stagecoach groups to manage fleets across all their British operating units, not restrict such processes to within Scotland.

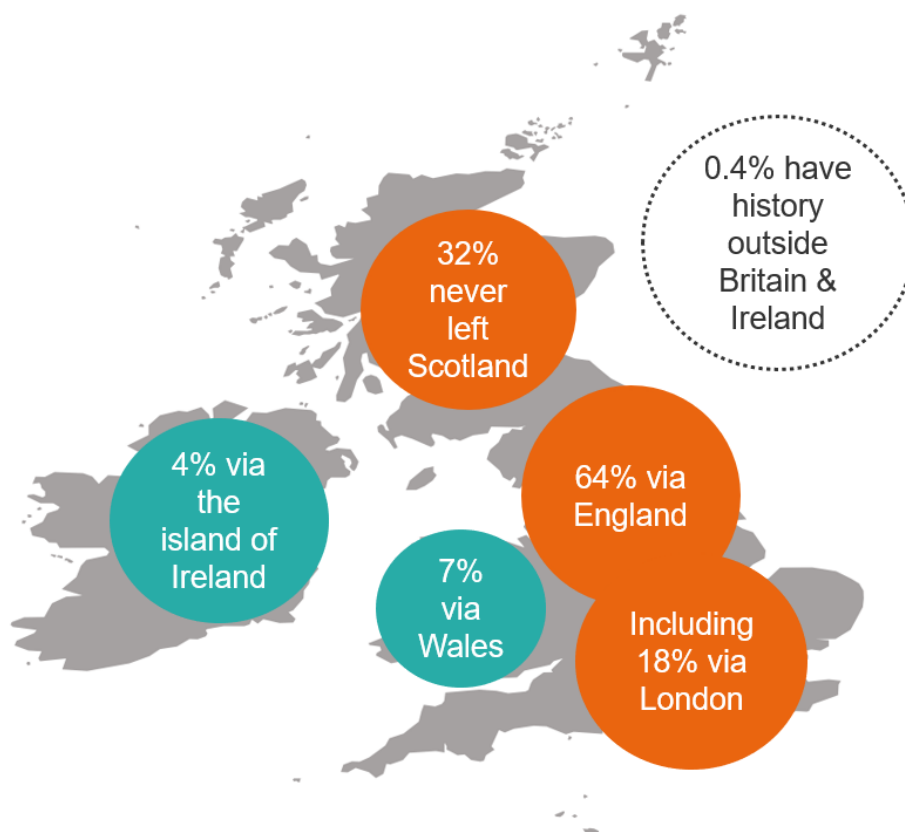


Figure 3: Inter-nation transfers of all vehicles built from 1997 until 2007 with history at one or more Scottish local bus service operator¹¹ (base map © EuroGeographics)

The existing second-hand market is interdependent with the rest of Britain and Ireland. But there is no structural reason that makes this interdependence strictly necessary: Inbound roughly matches outbound – overall flows balance. Consequently, Scotland could potentially manage its second-hand market internally if fleet investment or wider policy were to diverge significantly from England. This could grant policymakers the flexibility to tackle bus decarbonisation quicker or simply differently to England, although in practice that would imply a regulatory or funding intervention that effectively inhibited the free movement of buses. For example, requiring grant-funded buses remain in Scotland for 10 or 15 years, not five.

New bus deliveries have declined since 2010

Since the beginning of the 2010s annual deliveries of new bus and coach-bodied vehicles have declined significantly, with 2021 volumes a quarter of those in the 2000s. This can be expected to constrain future market supply.

The pattern can be clearly seen in the figures below, which show the absolute volume of new vehicles by body and year. The orange area highlights those with history at a

¹¹ Total sample 6,175. Vehicles built in this period have the most complete records of movement between operators, although not all have yet made their final journey.

Scottish operator. For coach bodies this means a history at any Scottish PSV operator, for bus bodies any Scottish local bus service operator.

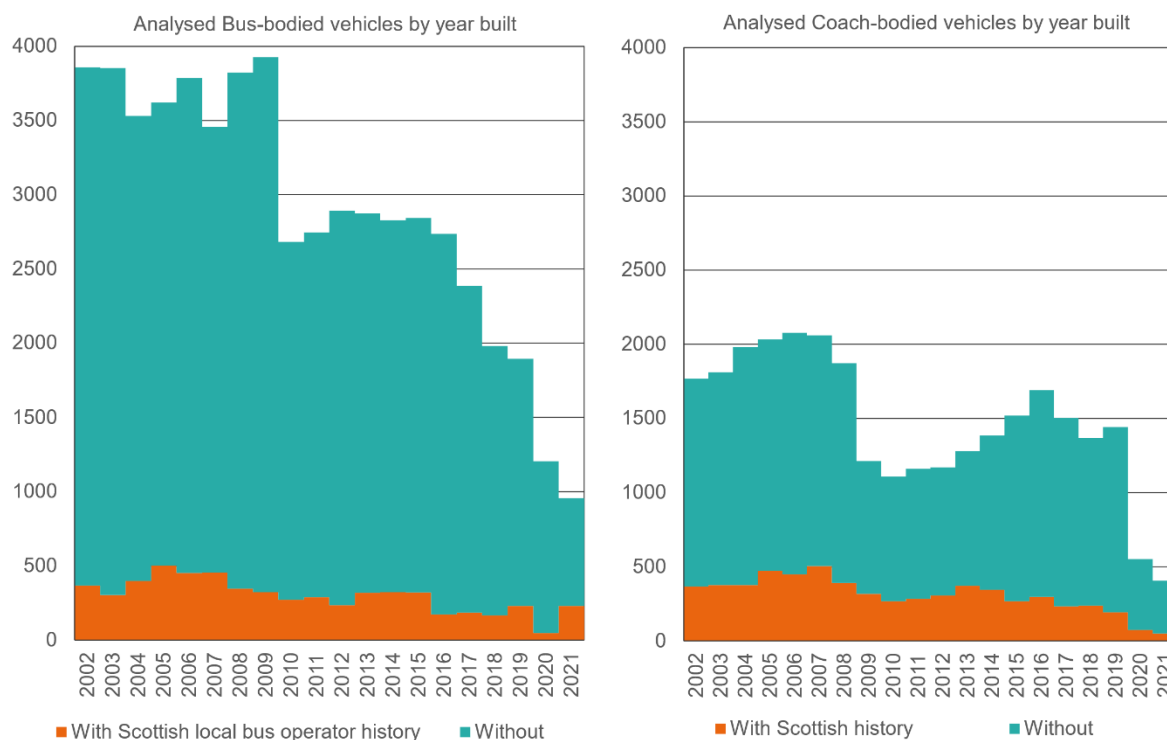


Figure 4: New bus and coach-bodied vehicles by year built, Britain and Ireland, highlighting vehicles with history at a Scottish operator

Coach-bodied vehicles are important to some Scottish local bus operators. But they are primarily shown below as a potential substitute to bus-bodied vehicles, especially in end-of-life roles. Substitution is pertinent to decarbonisation policy because any future Zero Emission Vehicle mandate for coaches is expected to lag years behind that for buses¹². Any future local bus operator unable or unwilling to operate a second-hand battery electric bus might seek to substitute a coach-bodied diesel.

One explanation for this pattern is wider economic optimism, or lack of it: Decline set in after the 2008/9 recession and subsequent era of government austerity. The decline in new bus-bodied vehicles is far more significant than any decline in local bus patronage. That suggests operators' sense of optimism, rather than mere passenger revenue, is a key factor, although we have no explicit evidence to support that conjecture.

The Covid pandemic of 2020-2021 decimated bus and coach patronage, and reasonably led to a slump in demand for new vehicles, further exacerbated by manufacturing supply chain bottlenecks. However, new bus-bodied vehicles were already in sharp decline in the years prior to Covid.

Over the last five years the number of new deliveries to London has more than halved. London may have clear bus decarbonisation targets,¹³ but it has evidently struggled to deliver upon them. Historically about 30% of all new bus-bodied vehicles in Britain and

¹² Ending UK sales of new, non-zero emission buses and calls for evidence on coaches and minibuses, DfT consultation, 2022,

https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1063585/non-zero-buses-coaches-minibuses-consultation.pdf

¹³ Mayor announces that all new London buses will be zero-emission, Mayor of London, 2021,

<https://www.london.gov.uk/press-releases/mayoral/mayor-host-zero-emission-bus-summit-at-city-hall>

Ireland have been new to London operators, so any slowdown in London will have a tangible impact on the Britain and Ireland fleet.

Scotland and the island of Ireland bucked the prevailing downward Covid trend, both receiving above-average volumes of new buses in 2021. 60% of all the new buses delivered to groups across Britain and Ireland in 2021 were to operations in Scotland or the island of Ireland (30% each) – more than triple the proportion that might be expected based on operational share.

If 2016-level deliveries of bus-bodied vehicles had been maintained through to 2021, then roughly 5,200 additional vehicles would now be in the fleet: The equivalent of two years of new vehicle production has been lost in the last five years. If vehicles are assumed to last an average of 20 years (justified in 0), roughly 10% of the future second-hand fleet has already been lost. Operators have remained under considerable commercial stress during 2022, making it unlikely that new deliveries will recover rapidly.

For comparison, little change in the overall Great Britain local bus fleet was recorded in official statistics¹⁴ from 2004 until around 2013. Since then, total fleet has declined 10%. It is difficult to correlate fleet patterns to new build without understanding new build in the decade prior to 2002, because most buses have a 15-to-20-year lifetime.

Implications for second-hand bus market supply

The relatively constrained nature of the British and Irish second-hand bus market means that supply-side declines over the last decade are now largely baked in and will inevitably lead to subtle shifts in market dynamics. Scotland's current interdependence with England means she cannot evade the long-term effects of recent declines in new build in England, even when Scotland herself bucks the trend. This subsection discusses these subtle shifts in the dynamics of the current market for predominantly diesel buses. The further structural change related to bus electrification will be considered in chapter 4.

New vehicle volumes declined by over a quarter from the 2000s to the early 2010s. Over the next five years end-of-life operators can therefore expect to find it more difficult to acquire vehicles. The pool of vehicles in the end-of-life market could almost have halved by the mid-2030s, assuming an overall Covid-era decline of up to 20%. Interviewee comments suggest the price of mid-life buses on the second-hand market is already rising tangibly – a combination of supply-side constraints and buyers lacking the confidence to buy new.

Many school contracts traditionally presume the use of end-of-life vehicles: Home-to-school pupil transport is a statutory local government responsibility where contracts are awarded primarily on cost, sometimes year-to-year. School bus duty cycles are typically minimal: Maybe two hours in the morning, repeated in the afternoon – and on school days only. Both factors suit largely or entirely depreciated buses.

However, the school contract business is evolving. Driver shortages, yet presumably stable pupil demand, have contributed to the emergence of a seller's market in parts of Scotland. Operators are responding by improving conditions for their drivers, one of which is age of vehicle driven. Operators may also now need to offer full time jobs to historically a "split shift" part-time workforce, which requires business diversification, thus longer duty-cycles, thus stronger justification for newer buses. School contract needs are already delivered by a wide range of vehicles – from taxis to coaches – which creates scope for continued evolution beyond buses.

¹⁴ BUS0601: Public service vehicle stock by type of vehicle: Great Britain, DfT, <https://www.gov.uk/government/statistical-data-sets/bus06-vehicle-stocks-technology-and-equipment>
The island of Ireland is not included, but represents less than 10% of comparative data.

Entirely new buses are currently hard to justify for school contract work because of the low intensity of school contract duties. We interviewed two operators that were actively deploying new or young buses on home-to-school contract work. These operators were reliant on either a secondary revenue stream, such as partnership with local schools for non-home-to-school travel, or reduced capital expenditure through the short-term opportunities that arise as manufacturers transition for zero emission designs. For example, a manufacturer may be prepared to subsidise the true price of a vehicle to test or showcase it with an operator, or simply to dispose of models made redundant by subsequent design evolution.

Overall, if demand is assumed to be stable, the implication of reduced vehicle supply is a readjustment in market dynamics. However, this pattern will be conflated by many other changes and uncertainties within the bus sector, explored in 0.

The only certainty is surely that the second-hand bus market will be less certain in the coming decade than in the past, which alone adds risk, which reduces investment (as explained in 0), which exacerbates supply-side constraints.

3.3 Drivers of the Scottish market

This section summarises patterns of life cycle and investment within the Scottish local bus fleet and explains how those tend to relate to local passenger markets. Key findings:

- A new bus typically works for 15 years on local bus services. Only 5% of buses remain with their initial operator for the whole of that period. On average, a bus can expect to work for three to four different operators during its life.
- Overall, SME local bus operators are just as likely to acquire new buses as the larger bus operating groups.
- The largest groups follow competitive instinct and tend to deploy their youngest buses to places where there is greatest on-road competition.
- Overall, SMEs invert that pattern, with the youngest fleets associated to local territory with the greatest dominance. SMEs operate in market niches and tend to favour more rural territory for newer buses.

The lifetime of a bus

Buses typically work 15 years in mainstream local bus operation, potentially followed by low duty intensity end-of-life roles. Most buses are scrapped by age 20.

Figure 5 shows the probability of different types of move in each year of a bus's life. Probabilities are used instead of absolutes because the overall fleet profile is skewed by age (as described in 0), and because many individual buses in our dataset are only detailed for a part of their whole life: For example, buses built in the 1990s are recorded only in the later stages of their life, while those built in the 2010s have not yet reached those later stages.

The solid grey line in Figure 5 shows that buses are most likely to move between operators when their age is 10-15. But movement is common prior, especially from age five. The long tail after age 15 reflects the gradual exit of buses from the market to scrap.

However, the difference between the (orange dotted) final record curve and (solid grey) any move curve implies around half of the moves at this late stage of life are still between operators, not scrapyards. The older the vehicle, the more certain it becomes that the final record indicates scrapping.

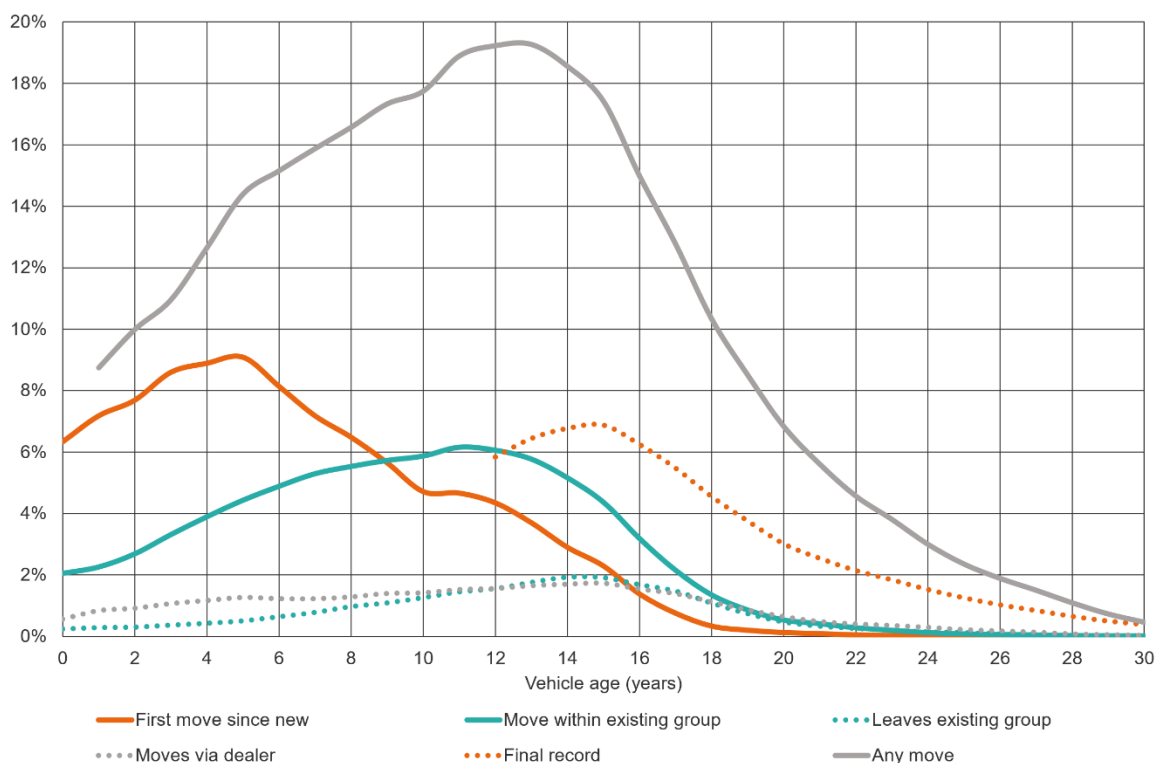


Figure 5: Probability of a move between operating companies in each year of a bus' life

The most likely age of the final record is 15 (shown by the orange dotted curve). 15 is also the most likely age for a bus to finally leave a group (shown by the green dotted curve). This combination suggests age 15 as the most likely time for buses to transition from mainstream local bus operation into end-of-life roles. In any given year post-15, just under half of those end-of-life *roles* are scrapping, not continued road operation.

This pattern broadly accords to operators' comments to the study team. Both First and Stagecoach groups are understood to depreciate vehicles over 15 years. For First, the actual decision to scrap a bus depends on the European emission standard of its engine (broadly aiming to remove the most polluting buses from the fleet first) and the amount of work the bus has done over its life. Lothian Buses assume 12 years within their business but expect some residual value via resale into the end-of-life market. Whitelaws, whose operations are less urban than Lothian, cited 17 years in total¹⁵.

When buses move between operators

On average, a bus can expect to work for three to four different operating companies during its life¹⁶. The second-hand bus market is not just a means of end-of-life disposal, but core to managing buses within the mainstream local bus sector: 95% of buses do not stay with their initial operator for the whole of their local bus service operating life.

The most likely age of the first move from the initial operator (the solid orange curve on the previous graph) is between three and six years, peaking at five. This is strongly influenced by the duration of:

¹⁵ For buses they buy new and sell into the second-hand market aged five.

¹⁶ Analysis of parsed PSV Circle data (described in section 6.1) indicates an average of 3.1 moves after new, plus one for the initial operator, minus one for the final non-operator owner, normally a scrapyards. However, records of moves to the scrapyards are particularly partial, so "three to four" is a more representative estimate.

- Contracts – for example, historically five-year London contracts commonly required new buses, with vehicles moved elsewhere afterwards.
- Manufacturer warranty – typically manufacturers guarantee parts on a new bus for three or five years, which operators may use to manage risk (see 0) – risk they need to offload just before the end of the warranty period.
- Public funding – for example, ScotZEB (Scottish Zero Emission Bus Challenge Fund) grants require new buses to be used on Scottish local bus services for a minimum of five years.

Commercial operators may also seek to maintain the competitiveness of core routes through five-yearly cycles of bus replacement.

Two thirds of first moves occur before age 10. Just 5% of buses remain with their first operator until age 15 – the age at which they are most likely to shift out of mainstream local bus work into end-of-life roles.

Moves within existing groups (for example, between two First operating units) broadly mimic the overall pattern of any move until age 15, then tail off faster (as shown by the solid green line in the graph above). The first half of that pattern suggests that groups manage vehicles internally much like the wider second-hand market, merely without the open market. The second half reinforces the idea that groups have relatively little involvement in end-of-life bus operations, and certainly little desire to maintain buses aged in their twenties.

Dealers include resellers, leasers, and some scrapyards that also resell (section 0 explains how dealers have been defined). Overall, just 8% of bus moves are *known* to involve a move via a dealer. However, based on operator interviews, we suspect the involvement of dealers is much greater than documented: Vehicles resold or re-leased quickly may simply not be noticed passing through dealers.

SMEs acquire new buses too

SMEs are commonly, but unfairly, stereotyped as operators of older, especially end-of-life buses. While some predominantly are, plenty are not. SMEs may also be framed as second users of buses that were originally built new for groups. This is also incorrect: Overall, within local bus operation, SMEs are just as likely as groups to acquire new buses. Business size, alone, has no obvious bearing on the decision to invest.

The chart below demonstrates this by comparing share of new buses (inner wheel) to share of local bus vehicle trips (middle wheel) and vehicle mileage (outer wheel). This analysis is intended to set new purchases in their broad context¹⁷. Vehicle trip metrics tend to over-emphasise *intra*-urban operations, while mileage metrics skew to *inter*-urban operations, but overall share is broadly similar across both metrics.

Overall, there is a strong correlation between operational share and new bus share: SMEs' new bus share is broadly in proportion to both vehicle mileage and vehicle trip share.

SMEs may be involved in mixed business models where coaches and minibuses *could* be used for non-local bus contract or hire work. 20% of the new vehicles included in the SME total are coach bodied, and 16% minibus bodied. So even if all new non-bus bodied vehicles at SMEs are assumed acquired for non-bus work (an unlikely scenario), SMEs would still be investing in roughly *their fair share* of new buses.

¹⁷ 2019 service and mileage metrics do not necessarily reflect all operations since 2002, although the overall shape of the Scottish bus industry has been reasonably stable over the period.

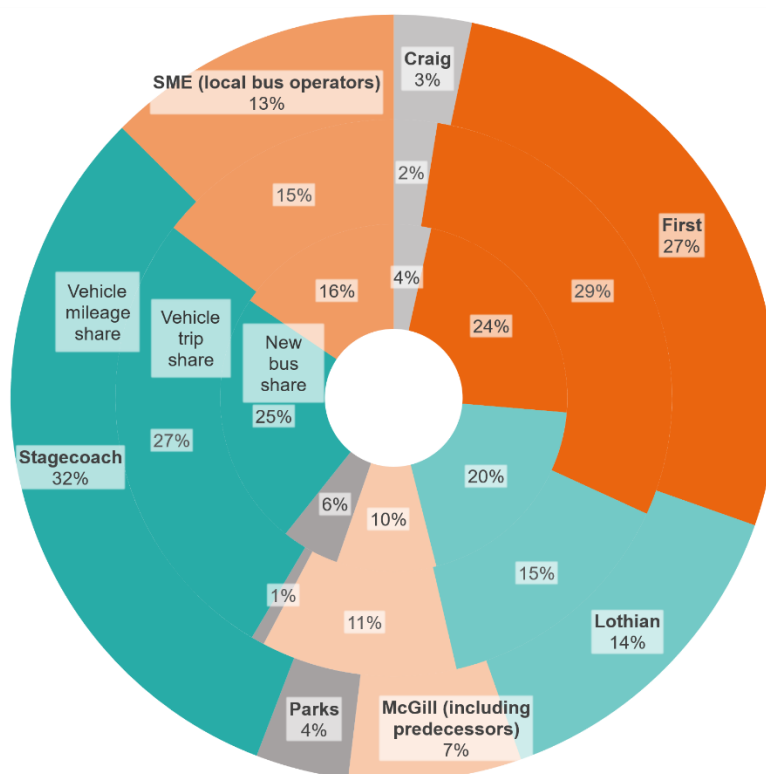


Figure 6: Share of vehicles new to Scottish local bus operators since 2002 (inner wheel) compared to the local bus service (middle wheel) and mileage (outer wheel) share, by group¹⁸

Fleet strategy and passenger market differ between operators

Operators share the same second-hand market, and similar overall tendencies to invest in new buses, but each operator has slightly different fleets and serves slightly different markets. These differences remain tangible when averaged across an entire group. The table below summarises selected bus fleet and passenger market metrics for the Scottish operations of groups in Scotland.

McGill has evolved into a substantial group over the last 20 years, much through acquisition. It acquired buses from many sources during that period, hence its relatively low historic tendency to internalise moves within what is now a group. Their approach has evolved, especially in the last decade, such that McGill now tend to buy new and manage buses across their life until scrappage, much more like most other groups.

First and Stagecoach attain similar levels of dominance within their local Scottish networks, but Stagecoach's territory is more rural, typically serving towns and interurban areas. McGill is less dominant, but with urbanity somewhat like First and Lothian. Craig is notable as being relatively rural, while not being especially dominant. Craig's market dominance primarily reflects very low dominance on corridors into Glasgow and Edinburgh, and to a lesser degree the relatively low frequency of rural services, which render almost any other local operator a tangible competitor.

¹⁸ A total of 4,860 new vehicles, 50 thousand daily (weekday) services and a million (weekday) estimated kilometres are included in the pie. McGill includes vehicles new to Scotland as Arriva Scotland West or Travel Dundee, with services assigned accordingly. First East (Central) Scotland (about 5% of all Scottish local bus services) is assigned to First.

Table 1: Selected Scottish bus fleet and passenger market metrics by group

Group ¹⁹	Bus fleet ²⁰			Passenger market ²¹		
	Estimated active Scottish fleet	Vehicle age when leaving group (years)	Tendency to internalise life within group	Dominance	Urbanity	Household average weekly income
Craig	260	16	High	49%	51%	£660
First	1,000	14	High	69%	89%	£680
Lothian	670	12	Medium	70%	93%	£740
McGill	540	12	Low	56%	90%	£660
Stagecoach	1,300	14	Medium	69%	71%	£700
<i>All groups (total/average)</i>	<i>3,770</i>	<i>13</i>	<i>-</i>	<i>64%</i>	<i>76%</i>	<i>£685</i>

The slightly younger age of buses leaving Lothian and McGill relative to other groups was confirmed by both during interview. There is perhaps a slight tendency for purely urban operators to retire buses earlier than more rural operators. That may reflect the stop-start nature of urban duty cycles on mechanical engineering. Note that the exception, First, is relatively urban in Scotland but manages its fleet across Britain,

¹⁹ Parks of Hamilton is elsewhere classed as a group but has been excluded from the table above. Parks is an exception because its business is primarily scheduled mid and long-distance coach. These duties are associated with relatively new vehicles operated intensively for a shorter lifespan than local buses: The average age of a vehicle leaving Parks' group is just five years, compared to 13 across the other groups listed above.

²⁰ The active bus fleet is that in (calculated as 70% of vehicle operator licences). The average age of buses leaving each group reflects patterns between 2002 and 2022. For First and Stagecoach this includes moves between any British operation, not just within Scotland. Group fleet strategies will have evolved over the period, so the bus fleet metrics should be read with caution.

²¹ Dominance is that relative to all other direct competitors, where 100% is an absolute monopoly. Urbanity expresses the rural-urban index as a percentage, where 100% is most urban. The method behind both is explained in section 0.

which includes less urban operating units – so like Stagecoach, cannot be generalised from the data in the table.

SME local bus operators average similar urbanity and income metrics to the groups, but far lower dominance – just 13% on average. SME local bus operators tend to serve market niches.

Passenger market matters and SME rationale can invert that of groups

Differences in operators' passenger markets are important because certain market characteristics tend to favour older or newer buses. And thus, we conclude it is underlying passenger markets that tend to frame operators' needs within the second-hand market. Further, it is here that SMEs genuinely diverge from groups, with different rationales for deploying buses to different passenger markets based on age.

Our data does not allocate buses to routes, only buses to operating companies. Indeed, not all operators allocate buses to specific routes, instead allocating only to depots, from which a range of routes are operated. We have therefore compared company-level fleet and passenger market metrics to look for statistically strong correlations.

First and Stagecoach operations across Great Britain have been analysed together to provide a more robust sample, of 41 operating units. Both First and Stagecoach exhibit almost identical patterns when analysed separately. These group representatives have been contrasted to the 31 large Scottish SME local bus operators – those running at least 50 vehicle trips per day. This criterion emphasises SMEs that are primarily local bus operators.

Average fleet age has been calculated as the mid-point between the ages of arrival to, and departure from, each operator's fleet, based on all such moves since 2002. Three tangible patterns emerged from regression analysis²²), each shown on the following graph:

- Groups tend to deploy the youngest buses to territory where market dominance is lowest – broadly, where there is greatest local on-road bus competition.
- SMEs invert this pattern, with the youngest fleets associated to the greatest dominance – but because they are small, the greatest dominance still tends to equate to a minority of all local services.
- SMEs also tend to favour less urban territory for younger buses – the equivalent statistic for groups is not a key driver.

²² The patterns identified attain R-squared of 40%, 24% and 31% respectively, where 100% would be a perfect correlation. We conclude these three factors are important determinants of the overall pattern but are not the only determinants.

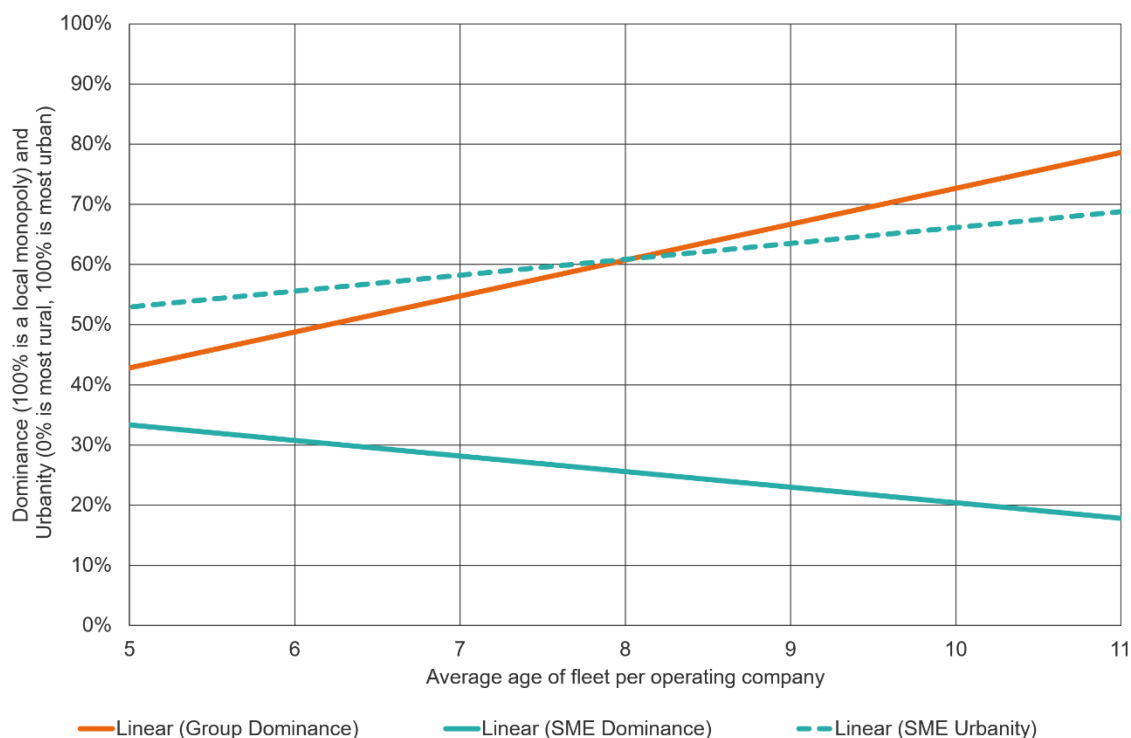


Figure 7: Fleet age by market – key linear trends for groups (First and Stagecoach) and SMEs

The group (First and Stagecoach) trend reflects a basic competitive instinct to offer one's best (broadly, one's newest) product in one's most contested markets. This is both to counteract competitors, and because contested local bus territory is generally the strongest commercially – precisely because it can support multiple operators.

SMEs emerge as niche operators. Some serve a local territory that is too geographically small or sparse to benefit from groups' economies of operating scale, but as a local business can commercially sustain new or recent buses. At the other end of the SME fleet age spectrum are niche urban operators, who typically provide a lower fare, out-of-hours, or wholly contracted service within a part of a dominant group operator's territory. For this they need cheaper second-hand buses.

From operators to routes

We have seen how the second-hand bus market is in part driven by differences in operators' passenger markets. How operators serve that passenger market – the structure of the routes within each operators' network – will become increasingly important as we begin to consider how decarbonisation will impact both fleet and second-hand market dynamics.

Every operation is unique because each reflects the individual local places and people within its territory. The best guide to investment priorities is the pattern introduced in 0 – from high to lower revenue-earning potential with age – but that must always be caveated by each operation's uniqueness.

The operators we interviewed tended to assign buses to geographically discrete depots, not to the specific routes operated from each depot. There are exceptions, for example where a bus is liveried to match a specific corridor. Depot-based allocations align only vaguely to specific passenger markets, typically by dint of geography. That can make it difficult to generalise investment decisions to those markets. But it is also indicative of the inherent flexibility within those decisions.

So, there is no common structure of operations that defines how buses are assigned to passenger markets. However, to aid discussion and analysis of the broad patterns of how operators serve markets we have attempted to create an ontology of route archetypes. Every uniquely numbered and operated route in Scotland has been assigned to one of five route archetypes (by the method detailed and quantified in 6.3):

- **City** – core high-frequency urban.
- **Interurban** – to regional centre from outside that region.
- **Rural** – primarily rural or smaller town inter-urban.
- **Suburban** – secondary urban – lower frequency, often avoiding centres.
- **Town** – primarily in or around mid-sized towns.

Our presumption is that, overall, city and interurban will tend to have higher earning potential (and thus be more likely to attract new or newer buses) than town and suburban routes. Our presumption does reflect the pattern of route histories for the small sample of buses checked during the bus fleet history data validation (see 0). However, modelling this in detail was not within the scope of the research.

The distribution between these archetypes of all the local bus vehicle trips provided by groups and by SMEs is shown in the figure below.



Figure 8: Proportion of all group and all SME local bus vehicle trips assigned to each route archetype

Overall, SME local bus operators (shown in green) provide a considerably lower proportion of city vehicle trips than groups (shown in orange). A considerably higher proportion of SME vehicle trips match rural and town archetypes. Both place similar emphasis on interurban and suburban archetypes. The radar graph above reinforces the earlier analysis that SMEs tend to slightly different passenger markets than groups.

Certain models or sizes of bus tend to be more suitable for certain route archetypes. These differences need to be managed within the wider constraint of high to lower revenue-earning potential with age. For example, a new double-deck bus may be perfectly suited to a high-earning city route when young, but not to a lower-earning rural route when older. This can define the geographical and market shape of some

operations, especially those seeking both fleet standardisation and localisation²³. For example, their network may be limited to those routes suited to a certain model or size of bus to allow a single standard fleet to be efficiently maintained and utilised. The larger and less predictable the fleet (dynamics especially caused by mergers and acquisitions), the harder it can become to match bus to route.

In this regard, mature SME local bus operators generally have an advantage over groups when matching bus to route: SME fleets are naturally smaller and more focused on specific local market territory, so overall more predictable and manageable at route level. This is potentially significant because battery electric buses, especially current models, are both restricted in range and best optimised (through active partnership with manufacturers) for discrete local operations. They have far less flexibility across different routes archetypes than prior diesel buses, as the next chapter explores.

²³ A dilemma explained in 0.

4 Looking to the future

As set out in Section 3, the second-hand bus market is described by the way buses move between operations, both within an organisation and through resale between organisations. The differences between groups and SMEs lie primarily in their ability to manage a bus across its whole lifetime, the markets in which they deploy new and older buses, and in the strategies that they use to manage risk.

There are several overarching challenges to adopting battery electric buses (BEBs) that apply across the market for new and used bus buyers. These issues apply to all operators regardless of size, although the implications and relative scale of the challenge might differ for smaller operators. These include:

- **Structural risks** within the Scottish local bus sector.
- **Limitations in battery electric bus duty cycles** meaning that BEBs are not fit for purpose.
- **Degradation of battery capacity** over time resulting in reduced vehicle range over time.
- **High upfront costs of vehicles**, primarily due to costs of the battery.
- **High costs and complexities of electrifying depots**, particularly in locations away from the grid and older, space-constrained depots.

To assess the impact that the transition to BEBs will have on the second-hand market, the next sections focus on the issues observed after BEB have entered the fleet. So, although electrifying depots can be a major barrier to BEB adoption, it is not a focus of this study. This is because it is primarily an issue related to where depots are located and the commercial viability of local bus markets.

Section 4.1 first describes these overarching issues in more detail. The implications of how bus operators might address these issues are then assessed in Section 0.

4.1 Overarching challenges in the transition to battery electric buses

Structural risks

Managing risk is the process of managing uncertainty. Bus operators must manage a range of different risks, including practical risks²⁴ and direct financial risks²⁵. Structural risks, the focus of this sub-section, are those that may fundamentally change the cost of doing business in a way an operator has little control over.

Major technology change will add risk to the local bus sector. Especially in the early stages of the transition when new technology is immature and unfamiliar, and its long-term limitations are unproven operationally. Technology change adds to existing uncertainties within the local bus sector, notably as it adjusts to post-Covid pandemic travel patterns, driver shortages, and wider economic and fuel price instability. Both pressures are piled upon a traditionally quite stable sector with little inherent capability or margin to manage such increased risk.

The organisational and financial structure of the local bus sector may itself need to evolve to manage this increased risk. It is clear that existing commercial operations

²⁴ Such as staff not having adequate training to maintain batteries safely

²⁵ Such as unexpected costs due to mechanical failure or unexpected changes to residual value of a vehicle

cannot simply switch buses and broader change to the sector's delivery and cost model will be necessary. Stagecoach have already suggested long-term fare rises in the order of 10%,²⁶ apparently before any risk premium from the transition itself is included.

The Scottish local bus market operates on low profit margins which creates little commercial capacity for trial and error. Relatively few BEB manufacturers have so far entered the British and Irish market,²⁷ in contrast to parts of mainland Europe. The requirement for manufacturers to work with operators much more closely on BEBs than on diesel buses will only emphasise the strength of "favoured supplier" relationships, focusing available capacity for trial and error. However, the overall lack of suppliers, and the lack of capacity to work across multiple suppliers, could constrain the rapid expansion in the bus fleet implicitly anticipated by decarbonisation mode shift goals.

The local bus sector manages shorter lifecycles than rail, so is better placed to deliver mid-term public transport decarbonisation objectives. But decarbonisation objectives cannot be achieved faster than the timeframe of existing bus lifecycles without severely impacting the financial balance revealed within the second-hand bus market. If buses have a working life in mainstream local bus operation of 15 years, then, all other problems resolved, the bus industry's pathway to decarbonisation should be assumed to take at least 15 years to steadily deliver.

High upfront cost and risk of batteries

Although running costs can be lower due to lower cost of electricity, battery electric vehicles can be up to 60-80% higher in upfront cost than diesel counterparts.²⁸ The battery makes up approximately 50%²⁹ of the total capital cost of the vehicle. Batteries degrade over time, and batteries are typically assumed to be no longer suitable for use in transport when they reach 80% of original capacity.³⁰ The rate of degradation of the battery is dependent on a number of factors, including external temperature, number of charging cycles and how the vehicle is charged over its lifetime.^{31,32} The BEB market is still maturing and there is uncertainty over how long the typical battery life will be. However, it is currently expected that the useful life of the battery will be in the order of five to seven years, after which it will likely need to be replaced to ensure the bus meets duty cycle requirements.

As described in 0, buses commonly move on from their first users before 10 years, and particularly from five years (see Figure 5, page 8). Therefore, it is likely that bus operators must make purchase decisions based on vehicle capability at the end of that time rather than at new. Operators must also manage the risk that they will need to replace the battery at least once within the time they operate the vehicle.

²⁶ Road map to zero, Stagecoach, <https://m.stagecoachgroup.com/~media/Files/S/Stagecoach-Group/Attachments/media/publication-policy-documents/zeb-report.pdf>

²⁷ Of the three current manufacturers (see 6.6), two are domestic within the United Kingdom. In contrast, over a dozen BEB manufacturers are active in the European Union (see The rapid deployment of zero-emission buses in Europe, ICCT, <https://theicct.org/wp-content/uploads/2022/09/zero-emission-buses-europe-sept22.pdf>)

²⁸ Element Energy analysis for the Climate Change Committee, 2020 [Element-Energy-Analysis-to-provide-costs-efficiencies-and-roll-out-trajectories-for-zero-emission-HGVs-buses-and-coaches.pdf](https://theccc.org.uk/Element-Energy-Analysis-to-provide-costs-efficiencies-and-roll-out-trajectories-for-zero-emission-HGVs-buses-and-coaches.pdf) (theccc.org.uk)

²⁹ Bartłomiejczyk and Kołacz, *The reduction of auxiliaries power demand: The challenge for electromobility in public transportation* (2020), <https://doi.org/10.1016/j.jclepro.2019.119776>

³⁰ <https://airqualitynews.com/2022/05/23/feature-how-to-avoid-battery-degradation-in-electric-buses/>

³¹ Including power rating of the charger, depth of discharge and average state of charge.

³² McGrath et al., *UK battery electric bus operation: Examining battery degradation, carbon emissions and cost* (2022), <https://doi.org/10.1016/j.trd.2022.103373>

Battery as a service (BaaS) models have emerged as a financing option to help manage the cost and risk of the batteries. Under BaaS, a third party owns the battery and leases it to the user. Although contracting and service types can vary, typically the third party guarantees to provide a battery on the bus that meets the minimum working capacity requirements. The third party takes ownership of any warranty and is responsible for replacing the battery when it reaches a state of degradation that is no longer fit for purpose.

By separating the bus purchase from the battery purchase and maintenance, the upfront capital cost of the bus can be reduced. The battery cost becomes an opex (operating) cost for the operator and, in some models, can be paid for through operating savings. As the battery is the component with the highest uncertainty,³³ the overall risk is also assumed by the third party, de-risking the process for operators.

Service contracts can be 5-15 years in length and can be combined with other services along the value chain, including infrastructure installation and management, and leasing of the bus body. Under current models, it is expected that buses will receive two batteries within their lifetime (assuming a 15-year contract); however, these models are relatively new and it may be the case that battery life is longer than expected.

Once removed from the bus, batteries are typically intended for second life applications, such as grid balancing or other stationary storage.³⁴ These second life applications can be lucrative and therefore more valuable than continued use in transport.³⁵ This means that while, in principle, older batteries could remain in buses for less demanding operations (such as school routes or other contract work), it is not guaranteed that they will be available if first users continue to use BaaS.

Limitations in vehicle duty cycle

The relatively low energy density of batteries means that there are trade-offs between driving range and passenger capacity. The current offering of battery electric buses in Britain and Ireland is limited to four main suppliers (see Appendix 6.6). Between them, these suppliers offer five single decker and two double decker options. The maximum battery capacity offered for a single decker is currently 567 kWh;³⁶ however, the typical battery capacity of vehicles planned or currently on the road is in the region of 350-400 kWh.³⁷ The listed driving range for these vehicles is up to 250-350 km on a single charge; however, in practice, the real-world range can be lower. This is due to a number of factors including: weather conditions,³⁸ additional power requirements, such as heating, and differences in terrain.³⁹

The limited driving range offered in the market is a major barrier to electrification. Most bus schedules operate without the flexibility for buses to refuel during the day. As such,

³³ In terms of potential for additional cost due to replacement, expected usable range over time, and component that is outside the skill set for operators to maintain in-house

³⁴ For example, VDL and RWE in Germany are beginning to reuse batteries for energy storage, <https://innovationorigins.com/en/selected/vdl-and-rwe-reuse-batteries-from-electric-buses-for-energy-storage/> (accessed 18th October 2022).

³⁵ Second-life applications outside transport can be accessed either by the bus operator themselves (if the battery is owned by the operator) or by the BaaS provider (if ownership is retained by the provider).

³⁶ For the Wrightbus GB Kite electroliner

³⁷ Based on details of successful SULEB and ScotZEB applications and bus operator public announcements

³⁸ For example, useable range has been reported to be 20% lower in winter than in summer (220 km in winter compared to 280 km in summer). Source: <https://www.route-one.net/features/national-express-where-hydrogen-is-fuelling-change/>

³⁹ For example, very hilly terrain will put more of a strain on a battery than flat, even roads.

the simplest transition to electric fleets would need the vehicles to be able to complete the full duty cycle between recharges.

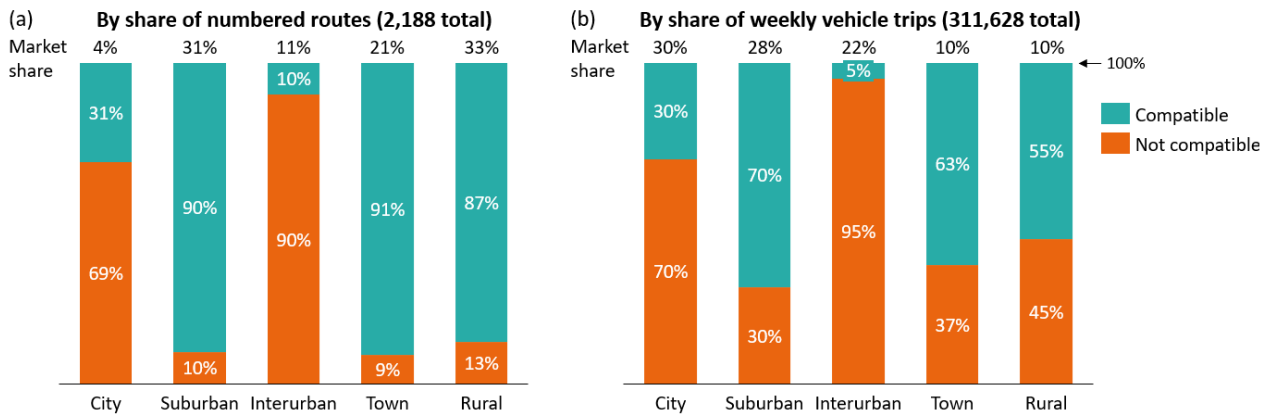
As shown in Figure 9, buses on the market today – as new – are not compatible with a high proportion of Scottish bus routes. As a share of all numbered routes (Figure 9a), 21% are incompatible. However, when weighted by number of vehicle trips on those routes (Figure 9b), this rises to 58%.⁴⁰ Figure 10 shows the estimated average battery capacity requirement across route types (see Figure 16, Appendix, for distribution of battery size requirement for each route archetype). This analysis is based on the following assumptions (see section 6.4, page 55 for full methodology):

- Vehicles charged from 20-80% battery capacity on a typical day.
- Vehicles operate the maximum number of vehicle trips possible within the full operating hours of the route.

The operational compatibility also reduces over time as the battery degrades such that 30% of numbered routes and 75% of vehicle trips become incompatible when the battery reaches 80% of its original capacity (Figure 9c and d). The reduction in range means that choices become more restricted as the bus ages, particularly towards the time of typical first move (see also section 0).

⁴⁰ We have used number of weekly services as a proxy for importance (profitability) of routes to account for otherwise under-representation of city routes within the data.

Compatibility of BEBs with current operating schedules – new bus, no opportunity charging



Compatibility of BEBs with current operating schedules – 80% original capacity, no opportunity charging

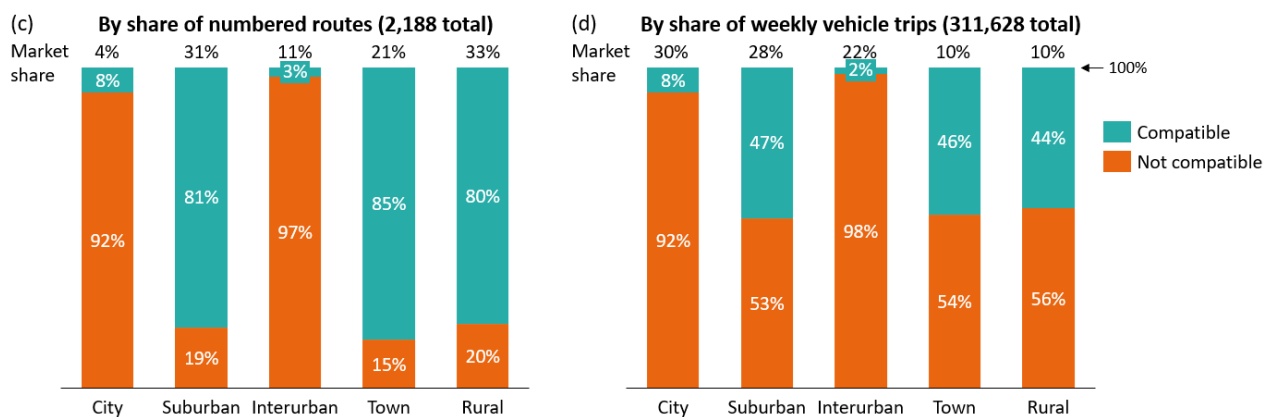


Figure 9: Estimated compatibility of current battery electric buses for Scottish local bus routes when new (top) and after approximately 5 years (80% remaining capacity): (a,c) by share of numbered routes and (b,d) by share of weekly vehicle trips. Assumes single decker with 420 kWh battery, only charging from 20-80% on a typical day, operating for the full operational hours of the route.

Average battery size requirement of current Scottish local bus operating schedules

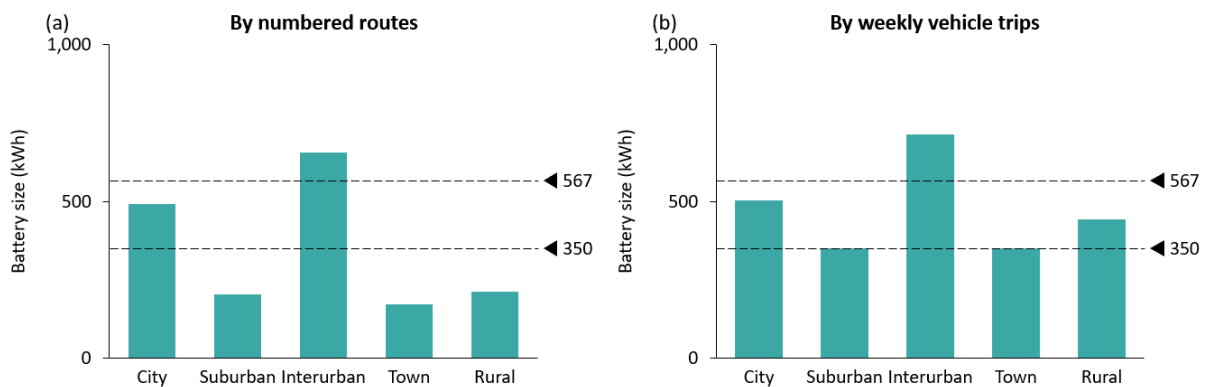


Figure 10 Estimated average battery size requirement of operating schedules by route type (a) by numbered routes and (b) weighted by weekly vehicle trips. Current range of battery capacity offered by manufacturers is indicated by the dashed lines (single decker).

This analysis should be considered as indicative of the scale of the challenge only since it does not fully capture all aspects of bus duty cycles. For example, we have only considered mileage requirements for vehicles driving on the route itself and have not included the distance required for the bus to get from depot to the start of the route (positional mileage; see section 6.4, page 55 for further discussion of limitations).

However, it highlights that operators are currently limited in where they can use electric buses.

As shown in Figure 9, all route archetypes have a share of routes that are not compatible with current vehicle driving ranges. However, our analysis shows that the majority of incompatible routes are city and interurban routes. City and interurban routes together represent 55% of all weekly vehicle trips, with 59% and 90% of these incompatible with current BEBs, respectively (Figure 9b). While the average city route battery requirement lies within the range of battery capacity available either on the road (350-420 kWh) or expected in the next year (567 kWh), the average interurban route requires much larger battery capacity (Figure 10).

The reason that these route types are challenging is that they have the highest daily mileage. For city routes, this is due to their very intensive duty cycles resulting from short routes (typically less than 30 km, 15 km average), very frequent services (average 19 hours, 100 or more vehicle trips per day) and very intensive scheduling. For interurban routes, this is a combination of moderate frequency (average 15 hours, 30-50 vehicle trips per day) and long route length (average 33 km).

As discussed in section 0, the high mileage on these routes means that we expect these two archetypes to contain routes with the highest revenue earning potential. This means that, while operators can and do deploy new buses on any route type, the routes that are most economically viable for putting electric buses on first are actually the most difficult to electrify.

This finding is counter-intuitive as it is commonly assumed that city routes are suited to electric buses and that second and later uses will be the most challenging. Indeed, many early electric buses have been deployed on city routes to-date.⁴¹ However, our analysis indicates that in fact the expected first use cases can be the most challenging and later uses are more suited to current technology.

Given that the market served by groups is skewed towards city and interurban routes, the impact of vehicle capability will tend to be higher for groups than for SMEs (see section 3.3.6). However, there are wider factors that constrain SME's ability to invest, for example, the greater risk faced in needing to transition a higher proportion, if not all of their fleet at once.

If the first use cases are the most challenging, then it is likely that the way that the first user of a bus adapts to limited range will dictate what happens in the second-hand market. It is these first-hand bus operator choices and their impacts on the second-hand market that we explore in the next section.

4.2 Impact of the transition to electric buses on the second-hand bus market

Addressing vehicle range

Nearly all electric buses on the road today are deployed on routes that our analysis indicates are suitable for the available driving range.⁴² However, since only relatively few electric buses have been deployed in medium-to-large fleets, operators currently have

⁴¹ Based on public announcements by bus operators.

⁴² The exception is the route operated by Stagecoach West which is exploring opportunity charging. See later discussion.

the option to support any shortfall in BEB range⁴³ by selectively switching BEBs for diesel buses on routes when and where needed.

In the short-term, operators that are electrifying their fleets will likely continue to deploy BEBs on the share of routes that are suitable (the blue segments in Figure 9) and supplement with diesel where needed. For those that are unable to do this, they will continue to not invest in BEBs. For SME local bus operators, supplementing with diesel is much less feasible as their overall fleet is smaller with lower availability of buses (spare fleet) to divert to services. Similarly, as a larger proportion of their fleets become electric, larger operators will no longer be able to continue to do this.

In the short-to-medium term, fleets also have the option to change fleet management practices to increase inter-working of vehicles across routes. By switching buses between routes throughout the day, daily mileage is distributed more evenly across vehicles. In the best-case, daily mileage can be matched to the capability of the BEB. The extent to which this is already done by operators varies. However, this is not feasible for all operators and mostly applicable to city routes where services overlap.

The need to assign BEBs to routes that are already suitable may force operators to move away from the principle of placing new buses on higher earning routes. It may also constrain the ability of BEBs to move via the second-hand market, constraining the dynamics of the second-hand bus market.

In the longer term, we expect that operators will manage the driving range limitations of new BEBs through a combination of:

- **Increasing battery capacity** to increase driving range and increase the proportion of compatible routes.
- **En-route charging** to maintain smaller batteries but extend the range by recharging more frequently.

Both improvements in battery capacity and on-duty charging rely on wider developments by manufacturers and in deployment of charging infrastructure. Both will therefore require strong collaboration between manufacturers and operators, as well as local partnerships to deliver the required change.

Increasing battery capacity

As the market matures, battery energy density is likely to continue to increase. With a 20% increase in battery capacities above the state-of-the-art today, almost all rural, town, and suburban routes will be compatible (Figure 11). An increase of this size is feasible over the next decade and so, by 2030, routes outside cities could be largely served by BEBs. In comparison, battery capacity would need to reach 1 MWh to ensure that less than 10% of interurban routes remain incompatible (see also Figure 16, Appendix, for distribution of estimated battery size requirement).

⁴³ For example, operators reported that battery electric buses have underperformed in the past due to difficulties with terrain, and additional challenges during winter months.

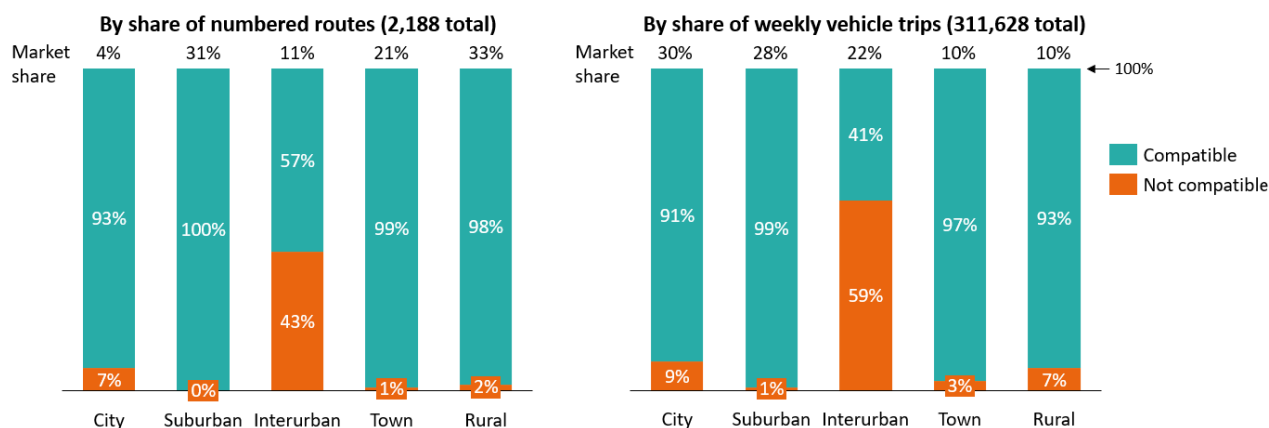


Figure 11: Compatibility of BEBs with Scottish routes if battery capacity increased by 20%

As more routes become compatible with the technology, buses will be able to be used across more of an operator's routes. For operators that already aim for a more standardised fleet, this will enable BEBs to be used in a flexible way that approaches that of diesel buses (i.e. able to be moved from route to route without difficulty).

However, improvements in battery technology also have impacts on vehicle design,⁴⁴ weight, and cost. Based on trends in the car market, improvements in technology have come before reductions in cost. Therefore, if the market relies on increases in battery size to reach widespread deployment of BEBs, there will be a delay in reaching cost parity with diesel. Delays in cost reduction will impact all owners of a bus across its life as the first user will face higher upfront costs but also will aim to maximise the residual value on resale.

If buses and batteries are sized for their first – or most demanding – use, it could mean that they will be larger than needed for some second use applications. This means that either:

- BEBs will either be more expensive at their second use, requiring every owner to increase their revenue-earning potential. This will likely price some owners out of the chain.
- BEB operators will need to accept lower residual value if or when selling on, or choose to depreciate their vehicles over a longer time period than they currently do. However, this depends on operators owning bus and battery, which is not the case under BaaS models (see also section 0).
- Operators may be able choose to reduce the size of the battery over the lifetime of the bus, to match the route requirements as the bus ages. However, there is no model that currently exists for this so it is not known if or how it would work with battery leasing or other contracting arrangements.

Matching the vehicle battery size to the route or location is a potentially more economical option for operators, both in first and later uses. In this case, the effect would be for fleets to tend toward being more diverse, with a range of short-, medium- and long-range options. More diverse fleets could allow for trading of vehicles between operators with similar route requirements in the second-hand market; however, this loses the advantage of flexibility within a fleet.

Opportunity charging

Extending the range of vehicles during service, without larger batteries, requires charging infrastructure outside of depots to be available. This process known as

⁴⁴ For example, where greater space is required to accommodate a larger battery.

opportunity charging involves placing high powered (300 or 450 kW) chargers in strategic locations for buses to use during their duty cycle. Charging can occur in minutes compared to hours for standard charging. This is an option that is being explored by Stagecoach West with vehicles funded through the Scottish Ultra Low Emission Bus Scheme (SULEBS).⁴⁵

Opportunity charging has been trialled and deployed in several areas of the UK, including Cardiff, Birmingham airport, and Harrogate. Harrogate is the longest-serving example, with BEBs running on primarily town routes since 2018 and recharging at dedicated bays at Harrogate bus station. However, all examples of opportunity charging to date are on relatively short loop routes (10-20 minutes, less than 10 km) and are predominantly Government-funded.

For opportunity charging to become commercially viable and operate without public funding, it is likely that chargers will need to have high demand. It is therefore more likely to be an option for high throughput areas such as cities. In principle, this could help mitigate issues in both city and interurban routes if suitable sites could be found. However, although Stagecoach's publicly-funded trial is exploring opportunity charging in rural locations, many rural locations are only served by a few routes (overall service level is primarily determined by population density) and therefore will not have sufficient buses passing each day to support a commercial business case. As such, gaps in the opportunity charging network may need to be permanently supported by public funding.

From the operator perspective, there are a number of other challenges that must be overcome in opportunity charging:

- **Many routes are not compatible** with charging at end stops. This is because schedules are already planned to incorporate minimal wait times at either end. If the bus needs to move to a particular location away from the end stop of the route, this adds time and ultimately would reduce the frequency of the service. Access to chargers would also need to be guaranteed to avoid additional delays.
- **Opportunity charging is demanding on the battery** and, unless the battery is optimised for it, will lead to a reduction in battery life if used regularly. This places a cost burden on operators that rely on opportunity charging, either through cost premiums for specialised buses⁴⁶ or through more frequent battery replacement. This will need to be reflected in any battery contracts, if used (see next section).
- **There is no standard for plug-in chargers** which means that rules around use of plugs and needs for staff training are unclear. To date, opportunity charging in the UK has exclusively used pantograph technology which did not require driver input. Going forward, it is unclear whether plug-in opportunity charging will be widely adopted (or adopted at all) or if other, innovative, options will also be considered. For all currently unproven technology, standards will need to be developed to provide clarity for operators.

Overall, establishing opportunity charging will require strong partnerships between operators and key destinations (for example, a local airport, retail hub, or leading employer) as well as cooperation between operators. Competition legislation often precludes direct collaboration between local bus operators, for example, multi-operator

⁴⁵ Vehicles serving Kilmarnock and surrounding areas will charge at an opportunity charging station at Kilmarnock bust station, <https://www.stagecoachbus.com/promos-and-offers/west-scotland/jul-21-introducing-our-new-fully-electric-fleet>

⁴⁶ Currently only the Volvo 7900e is designed for (overhead) opportunity charging.

ticketing relies on a block exemption from provisions in the Competition Act 1998.⁴⁷ . Therefore, third party support and structured local partnerships may be necessary to grow any potential network.

Alternative options – not using BEBs

All operators interviewed for this study considered hydrogen (out of scope for this study) to be a potential long-term option for supporting their operations. However, all interviewees acknowledged the need for the sector to mature and the uncertainty in its future role.

Ultimately, the primary option for operators to manage routes that couldn't be switched to battery electric through any other means is to continue to operate diesel vehicles. This option will become harder to maintain as the diesel market declines and regulation discourages new diesel from being purchased.⁴⁸ At such time that diesel can no longer be used but routes remain incompatible with BEBs, there may be a need to change the network structure and/or risk losing some bus coverage.

Implications of business models to address cost and battery degradation

The type of business model that operators choose to follow going forward will likely dictate whether there will be a second-hand market for BEBs.

If operators choose to pursue ownership or full leasing of bus and battery, then there is scope for vehicles to move between operators as they do currently. These models place more risk on the operator since they become responsible for both bus body and battery. Operators have indicated that they are open to ownership in the longer term but would need to wait until battery technology was more proven and to have developed in-house expertise in battery maintenance. However, in the medium term, it is likely that the majority of those who currently use BaaS will continue to do so.

If operators continue with BaaS models and ownership of bus and battery remain separate, the dynamics of bus depreciation and the second-hand market completely changes. This is because:

- **There is no longer a complete bus to sell on.** Although shorter term contracts (5 or 10 years) are offered, BaaS is still an emerging market and there is not enough real-world experience to know exactly how the dynamics between operators will work when those contracts end. It is unclear whether the battery needs to be purchased by the operator, which would create a complete asset that can be sold on. Otherwise, it may be that the bus body can be sold on, but the second user needs to continue a lease arrangement for the battery. Whether this is economical for the second user is unclear.
- **Depreciation of the battery is no longer under the remit of the operator.** Operators pay for battery performance rather than the battery itself. Since the battery is replaced regularly, the overall cost of an older bus is effectively close to or the same as a new bus if it needs the same performance. Effectively, the only way that the cost of the BEB reduces is if the battery is replaced with a smaller battery (effectively meaning the guaranteed mileage decreases). In some ways, this is advantageous from the perspective of avoiding oversizing of the battery at

⁴⁷ For further context, see Public transport ticketing scheme block exemption: call for evidence, DfT, 2022, <https://www.gov.uk/government/consultations/public-transport-ticketing-scheme-block-exemption-call-for-evidence/public-transport-ticketing-scheme-block-exemption-call-for-evidence>

⁴⁸ For example, through national regulation to end the sale of diesel buses or local regulation such as changes to low emission zone criteria. The latest consultation on national regulation ran March to May 2022, [Ending the sale of new, non-zero emission buses, coaches and minibuses - GOV.UK \(www.gov.uk\)](https://www.gov.uk/government/consultations/ending-the-sale-of-new-non-zero-emission-buses-coaches-and-minibuses)

the beginning of its life. Reducing the size of the battery over the life of the bus can allow some tailoring of the bus to its application. However, this is not an option that has been used yet and it's unclear whether it will be feasible.

- As the vehicles age there may come a point when **putting a new battery in an old bus becomes uneconomical**. From the operator perspective, as stated above, the cost of the new battery raises the cost of leasing to much closer to that of a new BEB. This means that the second user would need to use the bus in a higher-earning capacity than their current service. This would require them to adapt their business structure or choose not to adopt BEBs. In addition to this, as the bus body ages, it becomes the riskier asset. Older buses are more likely to fail, and operators may be particularly unwilling – and unable to afford – to invest in infrastructure to support a bus that may not last. In this case, BaaS contract lengths would effectively dictate the age of scrappage for buses.
- **There is competition for older batteries outside of the bus market.** Second life applications for batteries may well out-compete transport applications meaning that there are no older batteries available for older buses. A leading application for second life batteries is in battery energy storage systems (BESS) participating in grid services and energy trading. Second life BESS can generate similar value to new BESS per MWh of storage per year. Revenues from grid services are currently very high (£132/kW/year^{49,50}) and so present a good business case for second life batteries, although the market is currently relatively small. As the market grows and evolves, second life could continue to enable access to other services, such as energy trading, at a discounted price compared to new batteries. As such, bus operators cannot guarantee that there will be a second-hand option that serves their needs.

Overall, there will be segments of the bus market that will need to invest in newer vehicles than they do today, and this may not be viable for them. This is expected to particularly affect end-of-life operators, as the concept of a low or no-residual value bus ceases to exist.

⁴⁹ Through participation in frequency response services (for example Dynamic Containment).

⁵⁰ National Grid ESO, Dynamic Containment, Regulation and Moderation Auction Results, Accessed October 2022.

5 Conclusions

Summary of key findings

The key points from analysis of the current second-hand bus market are:

- To manage the financial risk around a depreciating asset, **operators currently transition buses from high to lower revenue-earning duties** with age. Operators rarely cover the full range of route types or earning potential ranges, so may use the second-hand market to transition buses.
- Scotland is integral to a wider British and Irish market. But **Scotland could sustain an internally balanced second-hand market**, potentially allowing Scotland to pursue alternative fleet policies.
- **New bus deliveries have declined since 2010**, and dramatically so after 2016, constraining future market supply.
- Constraints in market supply in turn mean that **the market will be less certain in the coming decade** than in the past. Fluctuation in the balance of demand and supply, and thus residual value in the second-hand market, adds risk, which could reduce investment and further reduce the supply of buses to market.
- A new bus typically works for 15 years on local bus services. Only 5% of buses remain with their initial operator for the whole of that period. On average, **a bus can expect to work for three to four different operators** during its life.
- Overall, **small and medium-sized enterprise (SME) local bus operators are just as likely to acquire new buses** as the larger bus operating groups.
- The largest groups follow competitive instinct and tend to deploy their youngest buses to places where the group is least dominant locally. SMEs invert this relationship to passenger market, with the youngest fleets associated to the greatest dominance. **SMEs operate in market niches and tend to favour more rural territory for newer buses.**

Key points from consideration of the future market:

- **More than half of Scottish local bus vehicle trips** currently operate in a manner **incompatible with current battery electric bus (BEB) capabilities.**
- **The most challenging route archetypes to transition are those that are expected to have the most potential revenue** and therefore would be the natural choice for deployment of new BEBs.
- **Expected improvements to battery capacity should solve most incompatibilities by 2030.** Matching the capacity required for first use will mean vehicles tending to be higher specification than needed for second use. That may engender less fleet standardisation. Higher BEB capital cost (compared to diesel) implies high residual value at resale into the second-hand market.
- Remaining BEB-to-route incompatibilities are expected to primarily affect core interurban style operations, plus some intensely operated city urban routes. **Opportunity charging could be a viable strategy** here, although raises cost issues (both as infrastructure and as increased rate of battery degradation), and operational and scheduling issues.
- **Battery as a service (BaaS) will fundamentally change the structure of the second-hand bus market:** Bus and battery are owned separately.

- Rather than simply balancing earning-potential to bus age, operators effectively buy a capacity/mileage guarantee, which does not “depreciate” on the same basis as the bus part. **Battery contract periods could frame the age of bus scrappage.**
- **The second-hand battery market is far broader than just buses.** Current end-of-life users will compete in that battery market. So, we should assume that there will be no end-of-life bus market. Many school contractors will need to shift towards younger fleets, which can only be justified by more intensive use, implying more mixed business models.
- **Overall, there will be segments of the local bus sector that will need to invest in newer vehicles than they do currently,** but that may not be commercially viable for them.

What remains uncertain

Further issues were raised by the study that could have an impact on the second-hand bus market, but on which our evidence is insufficient to draw firm conclusions:

- Operators currently move buses from high to lower revenue earning roles over their life, so earnings mirror depreciated value. This is core to second-hand bus market dynamics. However, operator decisions are far more nuanced than our broad model of route archetypes can capture. So, **we cannot precisely assess where buses of a certain age are deployed,** and thus cannot precisely forecast how BEBs might change that.
- Unless the bus sector declines by over 10%, the two years of lost new bus production since 2016 imply **supply-side shortages in the second-hand bus market.** These will **need to be made-up by accelerating new deliveries** through the 2020s, logically of BEBs. Mode shift objectives imply even more buses. It is not clear how feasible that acceleration will be, especially given the small pool of manufacturers currently offering BEBs in Britain and Ireland.
- **Batteries fundamentally change the equation on residual value.** Diesel buses depreciated from new to scrap almost wholly within the local bus industry. Older batteries are expected to have an end-of-life role outside of the bus sector. The residual value at which a battery switches from bus to end-of-life is unclear. But it seems entirely likely that there will be no end-of-life market for BEBs as a result. And it is possible this switch will affect buses towards the end of their local bus operating life. In future there may be no such thing as a “cheap bus”, but how cheap is cheap?
- BaaS is a popular way of managing risk during the transition, but **it is unclear whether the battery leasing model will persist** with such dominance in the long-term. Operators could eventually learn to manage that risk themselves, and thus, like conventional leasing, BaaS would become a niche business model best suited to new entrants or rapid expansion. Without BaaS dominant, the second-hand bus market may not perfectly split in two, although the wider second-hand battery market would still have influence.
- **The wider second-life battery market is rapidly evolving.** The value of second life applications (particularly deployment in energy trading and grid services) present opportunities for second life batteries both now and in the future as both grid-scale energy storage and second life battery marketplaces mature. It is unclear whether end-of-life bus use will be able to compete with such options.

- The ongoing need for active partnership between local bus operators and their suppliers, and the **more precise engineering of both BEBs and supporting infrastructure** to discrete route duties, will all make trading buses between operators more difficult than prior. Yet like BaaS, these **may be transitional trends** which fade once the technology matures.
- **The future balance of battery capacity and capital cost** raises further uncertainties. For example, range increases that come at the same or greater cost than existing batteries may solve the operational limitations of BEBs, but not necessarily in a commercially viable manner.

What is most likely

Given all the learnings and caveats on uncertainty above:

- **The short-term** is the current period, when the transition is expected, but has not yet begun in earnest. The local bus sector lacks confidence to invest in BEBs. This is currently due to a combination of uncertainties, both baseline uncertainties such as post-COVID patronage recovery, and decarbonisation uncertainties, such as future battery capabilities and depreciation. This is already evident in the volume of new buses delivered in recent years.
- **The mid-term** commences once short-term uncertainties are overcome and the transition to BEBs is occurring but is not yet complete. Operators may have a clear objective, but the entire local bus sector, not least the second-hand bus market, will be in flux: Supply-side shortages for older buses, initially reflecting historically low deliveries of new buses. Operators will have to compromise between revenue-earning potential and route compatibility on the BEBs they do acquire, while beginning to adjust their commercial and accountancy assumptions to match BEBs. Operators will tend to over-compensate to manage unfamiliar risks and uncertain business assumptions – so extra costs, real plus imagined, are most significant mid-term.
- **The long-term** is reached once BEBs are widespread and technologically mature. The pace of change reverts to that prior, but with new assumptions. Local bus operators have considerable flexibility in BEB assignment to routes. Cost and depreciation models will be different, but stable. Operators' accumulated understanding of batteries will allow reassessment and optimisation of strategy on BaaS. Operators previously emphasising end-of-life bus will adjust their business models to support younger buses or leave the market. Readjustment in specific markets (such as home-to-school), or reappraisal of strategic competitive advantage (such as group or localised fleet management), may cause further isolated turbulence.

Where we go next

As originally proposed, our study was primarily intended to highlight BEB transition issues for SME local bus operators. A common assumption is that SMEs rely more heavily on the second-hand market and therefore will experience different challenges to those faced by large groups. We found:

- SMEs tend to operate in slightly different local passenger markets to groups and tend to deploy younger buses with different priorities to those markets. But the issues they face when trying to match BEB capabilities to routes can be much the same as those faced by groups.
- SMEs are visibly more active in the open second-hand bus market. But they are ultimately managing a similar sort of calculation around fleet, earning potential and residual value as the groups.

- SMEs deploy different strategies to managing the risk associated with a bus's depreciating value. But the underlying issue is one groups face too.

There are specific issues facing SMEs looking to electrify their local bus fleets, and many of those have been touched on in chapter 4. Existing end-of-life users, notably many home-to-school contractors, will almost certainly have to evolve towards younger vehicles – and perhaps therefore more mixed business models.

The key point is that most of the big issues we have identified could affect Scottish local bus operators of any size.

The key finding from 0 is that more than half of Scotland's local bus vehicle trips will not readily convert to BEB operation using existing BEB models on existing operating practices. That half varies by operator. The fortunate can worry about solving what does not convert closer to 2030. Others are trusting that technology will advance at pace. But plenty of operators are already actively facing the dilemma.

There is a need for better understanding of the practical limits of BEBs, not just so operators can better plan their investment strategies, but also help facilitate productive dialogue with government and help develop a shared policy agenda.

Yet that is just the first of many uncertainties faced by the local bus sector. Section 4.1 outlined many other risks. No one issue is insurmountable. But taken together they may increase the burden of risk on local bus operation such that operators start to exit the business. Those operators are needed to deliver policy objectives of mode shift to bus.

While improved research and prediction can moderate some of the uncertainties of the transition, many are inherent and likely unavoidable. So at least in the short-to-midterm, there is a need to improve the local bus sector's capacity to manage risk.

6 Appendix

6.1 Bus fleet history

This section details the method used to source, extract and validate data describing bus moves between operating companies over the last two decades.

An introduction to the PSV Circle's News Sheets

Government data on bus fleets is primarily collected by the Department for Transport's Driver and Vehicle Standards Agency (DVLA). That data consists of vehicle registrations⁵¹ and operator licence records⁵². Neither makes a distinction between public service vehicle (PSV) and local bus operation. Neither published dataset records the current location of buses over time in such a way that allows moves between operators to be analysed.

Instead, we have processed bus enthusiast information, specifically that gathered between 2002 and 2021 (inclusive) by the PSV Circle. The PSV Circle was established in 1943 and is generally considered the most authoritative source by the enthusiast community. The organisation has six or seven editors in Scotland alone, who compile reports from both operator contacts and local members.

We have processed the PSV Circle's News Sheets⁵³. These are monthly hand-typed updates, by operator, primarily of buses inbound and outbound at each PSV operator. Annual archives can be purchased for a small fee from the PSV Circle. They own the data, so we are not able to publish vehicle-level results. Our processing and subsequent analysis has not been endorsed by the PSV Circle.

The information within each News Sheet is structured for an expert human reader. For example, a reader that intuitively differentiates between operator and place names because they are familiar with both. Or knows that "AD" refers to manufacturer Alexander Dennis and is not the final two letters of a vehicle registration. Hand-typed records can use tabs and spaces differently from entry to entry, or split entries across multiple lines without warning. Non-numeric data, especially operator names, may be interpreted and written slightly differently by different authors: For example, over time a hypothetical "Mary's Buses of Herton Limited" could be expected to have half a dozen variations in punctuation or abbreviation.

As described in the next subsection, we have endeavoured to process PSV Circles' News Sheets as accurately as possible. But for some of the reasons outlined above, our processed dataset will not be perfect. Perfection is not required for this study's analysis. We require only a good approximation – enough to represent prevailing patterns fairly.

News Sheet parsing

A bespoke parser was written in the Python programming language, which:

1. Read through the entire News Sheet archive, tracking the ontology of information from sub-headings and *visual* cues such as spacing or punctuation, and extracting relevant data from the typed lines within. Only permanent moves between operators were captured, not temporary transfers.

⁵¹ Vehicle licensing statistics data files, DfT, <https://www.gov.uk/government/statistical-data-sets/vehicle-licensing-statistics-data-files>

⁵² Find lorry and bus operators, DVSA, <https://www.vehicle-operator-licensing.service.gov.uk/search/find-lorry-bus-operators/>

⁵³ News Sheets, PSV Circle, including samples, http://www.psvcircle.org.uk/index.php?route=information/information&information_id=10

2. Post-processed the extracted data, notably compiling registration-based events into unique vehicle histories by tracking and assigning re-registrations over time. Some operators use the same registration plates on completely different vehicles every couple of years.

For each vehicle processed as unique, the consistency of data associated with that unique vehicle was assessed: Body, decks, seats and built date. Some of these metrics, such as seat count, can legitimately change over a vehicle's life. Build dates are prone to small margins of error. The sum of such differences over all the records associated with each unique vehicle was expressed as a percentage and used to exclude the most inconsistent.

Parser code was then iterated upon to reduce the proportion of all records that were excluded due to inconsistencies. For example, the logic used to recognise a vehicle registration was improved to separate that registration more reliably from a fleet number or chassis code on the same line. Our parser code was considered adequate once at least 95% of all records were successfully parsed into a unique vehicle with reasonably consistent descriptive data.

Multiple entries relating to the same move between operators were compiled into a single career story for each unique vehicle: A sequence of dated operator moves. A selection of vehicle stories were manually confirmed against dated photographs of buses found in enthusiast Flickr communities.

The table below gives an example of the career of one bus in our dataset. It illustrates how dated records of notable events across each vehicle's life can build a reasonably comprehensive picture of its career. This vehicle also exemplifies the lack of predictability inherent in some bus careers: For example, the acquisition of its first London owner by National Express Group, which led to an intra-group transfer, which was to Scotland – a path that could not have been reasonably anticipated when the bus was first built.

Table 2: Example - the life of the Optare Solo registered “YP 02 LCA”

Date	Operator	Record	Commentary
April 2002	Connex Bus (London)	New	Connex’s London operations changed owner in 2004, to become Travel London
July 2007	Travel Dundee	Move within group	Photographed operation within National Express Group’s other Angus-based subsidiary, Wisharts, is not recorded
June 2015	Travel Dundee	Withdrawn	Photographs from the time confirm damage to the front of the bus
Sept 2015	JP Minicoaches (Forfar)	Move to SME	Geographically nearby operator, so possibly a locally brokered sale
May 2016	JP Minicoaches	Re-registered XIL 6467 & repaired	Smaller operators often re-register newly acquired buses, typically with plates taken from one of their former buses
Dec 2017	JP Minicoaches	Re-registered YP 02 LCA	Likewise, registering back indicates disposal, although there is no definitive record of scrapping

Operator names were standardised, so that *the same* operating company was referenced consistently across the dataset. Automated text parsing was used to compare and merge similar names. In practice this can only be used to adjust common abbreviations or single character errors, else North becomes South. For local bus operators with estimated contemporary fleets of at least 200 buses⁵⁴, both similar and historic names were standardised manually. These operators represent most of the bus fleet, but a tiny proportion of overall operator records.

As detailed in 0, the legal entity names used by the PSV Circle were related to modern trading names, primarily using Traveline National Operator Code (NOC) lookups. Notable defunct Scottish SME local bus operators have however been assigned as local bus operators, even though they have no modern NOC reference.

Historic entities were grouped into their current organisation where known. The Scottish bus industry has been relatively stable in structure over the last 20 years, so most data is not dependant on such assignment. The bus industry tends to agglomerate over time, so historic entities tend to fit wholly within a modern company. Where a historic entity did not fit precisely, the best fit was been used. This process was restricted to larger operators with histories that are well documented by internet sources. No attempt was made to map SME acquisitions.

⁵⁴ Estimated as 70% of their operating licence discs, via DVLA records.

The original PSV Circle data includes a small number of very historic records. For analysis within the study a bus must have at least one event dated 2002 or later.

Parser validation

Parsing the whole of Britain and Ireland dataset reduces the chance of specific records being missed due to unexpected formatting because almost every move between a pair of operators should be recorded twice – once from origin, once at destination. Buses with a history at a PSV Circle “major operator” (typically group operating units) are commonly referenced again in a “subsequent history” section. This inherent duplication of most data greatly improves the reliability of overall data extraction, since in most cases the parser has two or more chances to extract each event in a bus’s life.

Over its life, a bus can expect to move between operators three to four times (as explained in 0), each of which is referenced at least twice, so the probability of not capturing data on each vehicle at some point in its life should be extremely low. In contrast, records of when and where a bus was new should only exist once. Most records of vehicle movement also cite the vehicle’s date of manufacture. So, we can calculate the proportion of all buses manufacturer in each year that were located by the parser when new. This is plotted on the figure below for bus-bodied vehicles. Bus-bodied vehicles dominate the data used in the study itself.

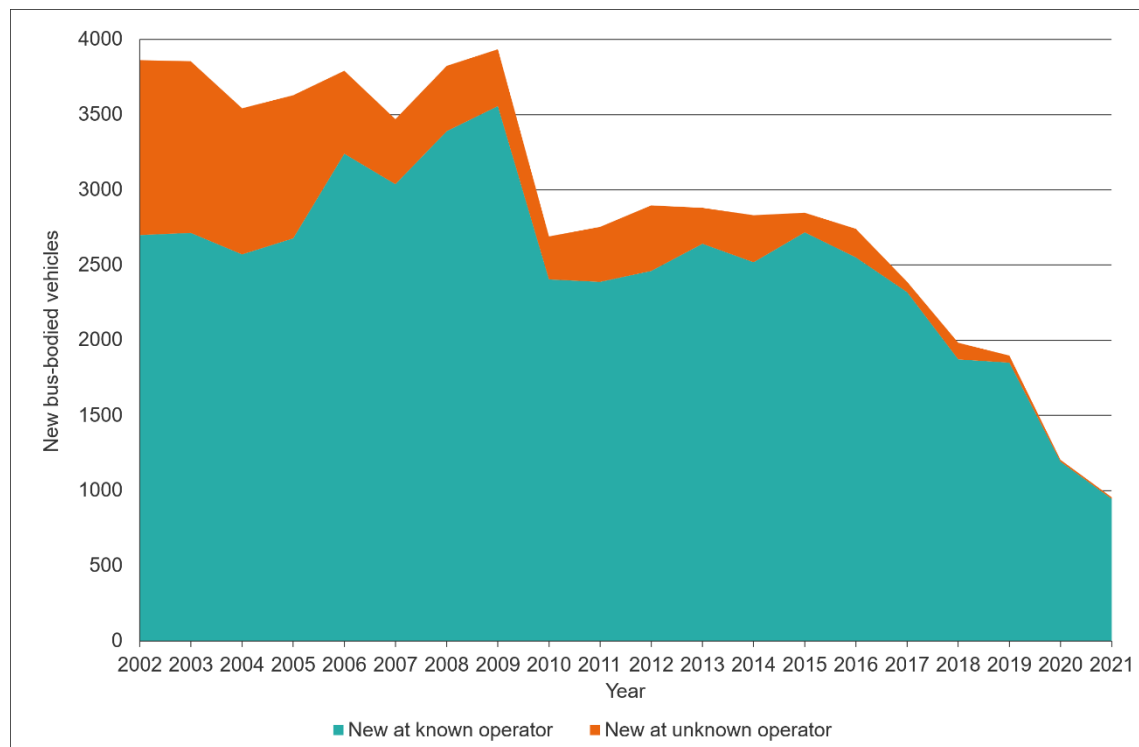


Figure 12: New bus-bodied vehicles by year built and initial operator (whole dataset)

The orange-shaded area – bus-bodied vehicles with no initial location recorded when new – is effectively the error in recording any one single event described by the original News Sheets. This error is understated among the youngest buses, where the first move since new has perhaps not yet occurred, and thus the bus is not yet known unless recorded as new. However, as detailed in 0, the most likely age of first move is five years, with two thirds of first moves by age 10. This implies the error between 2006 and 2021 is 10-15%. Between 2002 and 2005 errors are higher, up to 30%, which reflects different standards of formatting in that period (when presumably production was still adjusting to modern electronic formats).

Although a 10-15% error on any one event is significant, that error should apply independently to each text in the News Sheets a vehicle event is recorded. Since all but the first and final records should be parsed at least twice, the risk of missing a move between operators entirely is estimated as under 5%. Such a parsing error is unlikely to significantly impact subsequently analysed patterns.

Review of bus fleet data

The table below summarises the fleet within our parsed and processed data, for the whole of Britain and Ireland. The table shows values across the entire dataset and values for only vehicles with a history at a local bus operating group. The whole dataset covers a wide range of PSV operators, including those primarily in coach, education, or community (social care) sectors. In contrast, the groups are almost entirely focused on local bus operation, so expose key differences in fleet make-up between local bus and the wider PSV sector.

Table 3: Size and makeup of parsed/processed fleet (all data across Britain and Ireland)

Descriptor	Category	Whole dataset	Only vehicles with history at a local bus operating group
Known vehicles (total sample)		260,250	76,050
Body	Bus	40%	86%
	Coach	27%	12%
	Minibus	32%	1%
Decks	Single	83%	58%
	Double	15%	40%
Seats (average per vehicle)		36	52
Has history	In Scotland	15%	18%
	At a Scottish local bus operator	6%	16%

Our parsed dataset captures all vehicles active between 2002 and 2021. Over those 20 years the entire fleet will effectively have been replaced once, so we should expect to have recorded in the order of twice the fleet size in any one year. The United Kingdom

typically records⁵⁵ a fleet of 150-200 thousand licenced PSVs at year end over this period. Approximately 10% can be added for the Republic of Ireland.

Our parsed data has roughly the correct magnitude of total vehicles but is missing around a third. However, just over half of officially recorded licenced PSVs are minibuses, while our parsed data records only a third as minibuses. Factor in those missing minibuses and we would have expected about 350,000 vehicle records, which is roughly double the official fleet size in any one year.

So, excluding minibuses, the volume of parsed data is broadly as expected. Minibuses are very rarely used in mainstream local bus operation (as reflected by being just 1% of the group fleet). Consequently, any under-representation of minibuses will have no significant impact on the analysis within the study, which is focused on local bus service operation.

16,400 vehicles (the 6% in the table) are recorded as having history with a Scottish local bus operator. Just over half of these have been built since 2002 (as 0 describes, the bus fleet is skewed towards pre-2010 built vehicles). About 8,500 buses over 20 years, with an average life in mainstream local bus operation of 15 years (see 0) suggests an average Scottish local bus fleet of about 6,400 over the last two decades.

The Department for Transport estimates⁵⁶ an average of around 4,600 buses in Scotland between 2004/5 and 2020/1, with at least 5,000 buses in the fleet during the 2000s. Both methods are estimates, so we can be satisfied that each is of a similar magnitude, and that Scotland is not under-represented in our parsed data.

Dealers

Bus moves between operators that involve a third-party dealer may appear within the original News Sheets as a move first to a dealer and then to an operator. These records have been processed as a single move and merely flagged as via a dealer.

This processing requires a dealer to be defined. This is difficult because many entities that act as dealers are also operators, and the smallest dealers cannot always be distinguished from operators without further case-by-case research. We have therefore reserved the term for the largest dealers only. Entities that, from internet research, appear to be primarily dealers have been ordered by the number of references in the parsed data.

The top 30 have been assigned as dealers, plus a few smaller entities who are specifically active in Scotland, such as End of Life Vehicles (Rutherglen). On this basis Ensign Bus (Purfleet) is the busiest dealer in Britain and Ireland. They are involved in more than twice the volume of the next largest, BASE (Holmeswood Coaches). There then follows a long tail of tertiary dealers, starting with Pickford (Chippenham). All three of the named largest are also PSV operators.

6.2 Local bus services

This section describes the source and processing of schedule data describing local bus services, including the creation of route-specific metrics.

⁵⁵ VEH0601: Licensed buses and coaches at the end of the year by body type detail: Great Britain and United Kingdom, DfT, <https://www.gov.uk/government/statistical-data-sets/vehicle-licensing-statistics-data-tables>

⁵⁶ BUS0602: Number of buses by metropolitan area status and country: Great Britain, DfT, <https://www.gov.uk/government/statistical-data-sets/bus06-vehicle-stocks-technology-and-equipment>

Introduction to the use of open schedule data

A local bus service is defined as any road passenger service registered with the relevant Traffic Commissioner. Every service within the Traveline Scotland dataset⁵⁷ has been analysed, which includes scheduled longer-distance routes wholly within Scotland.

Data from the first week of April 2019 has been used. This period includes school term-time, so includes school-day variations and any school contract that is registered as a local bus service.

2019 data should be more typical of long-run bus operations than current data. It should now be treated as an optimism base case, an optimism that echoes the longer-term goal of both industry and Scottish government to shift journey onto bus, and thus substantially grow the bus market.

In current reality, many 2022 schedules contain service reductions relative to 2019, which reflect lower patronage post-Covid pandemic (both among peak commuters and pensioner concessionary travel) and operational stresses upon the industry (notably driver shortages and fuel prices).

Traveline National Operator Codes (NOCs)⁵⁸ describe public trading names and are used in open data schedules. To allow schedule-based route and market analysis to be compared to fleet histories, NOCs were related to the operating unit business names found in the parsed PSV Circle data (described in section 6.1) for every current local bus operator in Scotland.

Historic entities were placed into their current organisational structure where relevant. This was achieved through a combination of Traveline licence name lookup and desktop research. No adjustment has been made for changes in the bus network over time: 2019 might be expected to overstate the level of service in 2002, but exactly where would be much harder to estimate.

Processing of schedule and demographic data into local bus market analysis metrics

Traveline Scotland TransXChange⁵⁹ and supporting NaPTAN⁶⁰ stop data was first converted to GTFS (General Transit Feed Specification) using the Node programming framework's "transxchange2gtfs" library⁶¹. Non-bus modes, primarily ferries, were excluded. This GTFS was fed into the Aquius library⁶², which compiles schedules into route variations (repeated sequences of identical stopping patterns), attaches summary metrics (such as number of vehicle trips operated in each hour of the day), and builds a geospatial network of links between bus stops, throughout Scotland.

The results were combined with geospatial (Geojson) boundaries for Wards. Ward geography is a reasonable proxy for the catchment of most local bus routes – roughly walk-scale within urban areas, community-focused within rural. It allows the territory

⁵⁷ Traveline Open Data, <https://www.travelinedata.org.uk/>

⁵⁸ NOC database, <https://www.travelinedata.org.uk/traveline-open-data/transport-operations/about-2/>

⁵⁹ TransXChange, DfT, <https://www.gov.uk/government/collections/transxchange>

⁶⁰ National Public Transport Access Nodes, DfT, <https://www.data.gov.uk/dataset/ff93ffc1-6656-47d8-9155-85ea0b8f2251/national-public-transport-access-nodes-naptan>

⁶¹ Github, <https://github.com/planarnetwork/transxchange2gtfs>

⁶² Github, <https://github.com/timhowgego/Aquius>

served by each bus route to be related to demographic variables, including current mid-year population estimates⁶³, banded income statistics⁶⁴, and urban-rural classification⁶⁵.

The latter's eight-fold classification was converted into a single percentage index hereafter called "urbanity", where 100% would be entirely the most urban of the eight ("Large Urban Areas") and 0% would be entirely the most rural, with the six categories in between distributed equally between.

For each ward, the total number of weekday bus vehicle trips provided by each operator serving that Ward was calculated. A vehicle trip is a single end-to-end scheduled bus vehicle trip – a unique journey opportunity. Any scheduled service that stops within a given Ward is counted against that Ward. Multiple stops in the same Ward by the same service are counted once per Ward.

This passenger market analysis method is erroneous at local level, but adequate for the highly strategic purposes of this study. For example, when a Ward boundary follows the line of a street, an inbound bus route might be deemed to serve a different Ward to the parallel outbound route. In practice, over an entire network, these local discrepancies average out: In the example given, the out-and-back route genuinely serves parts of both Wards.

For each operator, the proportion of all their services in all the Wards they serve is calculated for each Ward. This proportion is then used to weight other metrics, such as urbanity or household income. For example, if an operator ran twice as many vehicle trips in one Ward compared to another, the urbanity of that first Ward would be considered twice as important when calculating the overall urbanity of that operator's passenger market.

The "dominance" metric calculates the local bus vehicle trip share of each operator across all the Wards they serve. For example, if one operator provided 100 vehicle trips in a Ward and the only other operator provided 400, the first operator's dominance would be 20% in that Ward. These Ward-specific calculations are weighted using the same method as other passenger market metrics.

Dominance helps understand the competitive strength of operators within their local markets. Scotland is notable in the British bus market in that her cities are more likely than England and Wales to combine high urbanity with a strongly dominant local operator. However, the use of Wards, rather than mileage, tends to understate the dominance of primarily rural operators that provide interurban: Their dominance on rural sections of the route is offset by minimal dominance on sections of route within cities, where dedicated urban operators dominate.

Parts of this network data processing were repeated for the whole of Great Britain to allow statistical comparison of group operating units and fleet age (used in 0 and for wider data quality checking). Similar data for the island of Ireland is available but was not processed and used in analysis because the island of Ireland is far less important to Scotland's second-hand bus market than Great Britain.

Review of bus market metrics

Processed schedule data has been sanity-checked to confirm:

⁶³ Mid-2021 Population Estimates Scotland, <https://www.nrscotland.gov.uk/statistics-and-data/statistics/statistics-by-theme/population/population-estimates/mid-year-population-estimates/mid-2021>

⁶⁴ Banded income statistics, 2018, <https://www.gov.scot/publications/banded-income-statistics-2018/>

⁶⁵ Scottish Government Urban Rural Classification 2020, <https://www.gov.scot/publications/scottish-government-urban-rural-classification-2020/>

- all expected (primarily group) operators are present,
- all expected geographic territories are covered, and
- logical calculations using comparative data, such as daily vehicle trips per bus in group operating unit's fleet⁶⁶, match expected magnitudes (in that case, in the order of 10).

The main quirk in the processed data was the separation of certain longer distance Stagecoach local bus services into fragments, which are not connected (in GTFS terms, “blocked”) together in the data, but are known to operate as through-services for passengers. This quirk does not alter the accuracy of the passenger market metrics but will affect certain derived route metrics (described in 0).

The figure below summarises hourly operations by group. Each one way vehicle trip is timed mid-journey. SMEs are divided in major (50 or more daily vehicle trips) and minor (which tends to include SMEs with mixed business models). McGill includes Xplore Dundee, but not First East Scotland (Central).

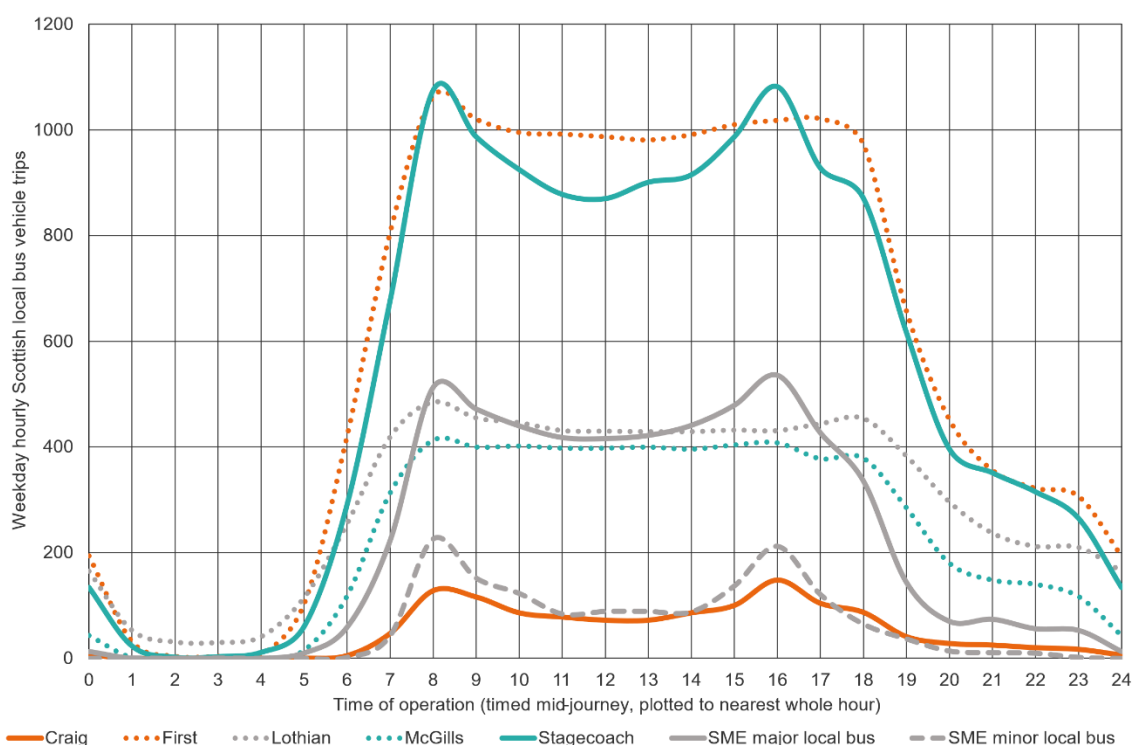


Figure 13: Scottish local bus vehicle trips operated by hour by group (weekdays)

Construction and review of route-specific metrics

Custom Python Pandas code was written to distil the processed schedule networks (created in 0) into metrics associated with each route variation.

A route variation is a specific sequence of stops, typically served by multiple vehicle trips. Most of an operator's numbered route consist at least two variations (outbound and inbound). Some routes consist of higher frequencies over part of the route, creating

⁶⁶ Active fleets for mainstream local bus operators are calculated as 70% of the operator's total (Vehicle and Operator Services Agency) licence discs – a proportion derived from statistical analysis of the big five British bus groups, selectively validated against sources such as Department for Transport Bus Open Data Automatic Vehicle Location data.

another pair of variations. Some routes vary at peak times, perhaps to serve a local school.

For each route variation (and operator), the following were calculated or summarised by day and hour of day, metrics averaged across all vehicle trips within that hour:

- Vehicle trips – count of scheduled end-to-end vehicle trips.
- Duration – end-to-end time running time.
- Stops – as scheduled, which may not imply every bus stops.
- Distance – based on Haversine (“crow fly”) distances between bus stops, which underestimates mileage slightly, especially on some rural or express routes, where road links between stops tend to be less direct.
- Express segments – distance over segments between concurrent stops of more than two kilometres, where it is likely that a route is using an express road, such as a motorway.
- Estimated minimum vehicle allocation – assumes no turnaround/layover or dead mileage, with no inter-working between other routes. For mid-to-high frequency routes, rounding this value up will be a reasonable guide to the route’s vehicle requirement. For infrequent routes, where inter-working between routes or split shifts (typically peak operation, with the driver off duty in the daytime) is more likely, this estimate of minimum vehicle allocation could be inaccurate.

Route variations were then grouped into routes, and for certain analysis operators or groups, by weighting each route variation by the proportion of all vehicle trips it represents.

A total of 10,404 route variations were identified across Scotland, equating to 2,188 uniquely numbered and operated routes. An average route in Scotland serves 31 stops, is estimated at 21 kilometres in length, and has an average speed of 26 kilometres per hour.

The most frequent route is First Greater Glasgow’s 266 Shotts/West Crindledyke-Hamilton, which operates every seven or eight minutes over its common section. Lothian Buses’ 100 Edinburgh Airport route is a close second and the most frequent route with no variations.

The longest single route, both in terms of distance and duration, is West Coast’s (as Scottish Citylink) Glasgow-Uig (Skye) – estimated at 255 kilometres over 310 minutes. The nature of that route, with large gaps between stops and predominantly indirect rural Highland roads, makes Haversine estimation especially unreliable – route length is cited elsewhere as about 370 kilometres⁶⁷.

6.3 Route archetypes

This section describes the five categories used by the study to describe routes, including a summary of metrics for each.

Construction of route archetypes

As discussed in 0, there is no universal ontology of operations that expresses how buses are assigned to passenger markets. However, to aid discussion and analysis of the broad patterns of how operators serve markets we have attempted to create an ontology of route archetypes. These archetypes try to encapsulate the range of different styles of operation found within the local bus sector.

⁶⁷ Britain’s longest bus route, Roger French, 2019, <https://busandtrainuser.com/2019/09/03/britains-longest-bus-route/>

The five route archetypes are described in the table below, alongside the metrics used to define them. The calculation of the metrics used are described in 6.2 above.

Table 4: Route archetype parameters

Archetype	Description	Weekly vehicle trips	Urbanity	Route length
City	Core high-frequency urban	≥ 600	$\geq 90\%$	$< 30\text{km}$
Interurban	To regional centre from outside that region	≥ 100	$< 90\%$	$\geq 20\text{km}$
Rural	Primarily rural or smaller town inter-urban	< 100	$< 50\%$	$< 20\text{km}$
			$< 80\%$	$\geq 20\text{km}$
Suburban	Secondary urban - lower frequency, often avoiding centres	< 600	$\geq 80\%$	$< 30\text{km}$
Town	Primarily in or around mid-sized towns	< 600	50-80%	$< 20\text{km}$

Ranges have been selected based on examination of the characteristics of a sample of routes. These ranges are presented as absolutes, but the aim is not to perfectly assign every route, rather to assess broad patterns of difference. That only requires that most of the routes be correctly assigned, not all.

Review of route archetypes metrics

The table below summarises key metrics across the whole route dataset. Comparison of the proportions of routes and vehicle trips show logical skews in importance: For example, city routes, which are defined as high frequency, account for few unique routes, but a far higher proportion of vehicle trips. Urban routes are substantially slower than rural.

Table 5: Summary of key route archetype metrics, across all Scottish local bus services

Archetype/metric	City	Interurban	Rural	Suburban	Town
Proportion of all routes	4%	11%	33%	31%	21%
Proportion of weekday services	30%	21%	11%	28%	10%
Average route length (kilometres)	15	33	31	12	10
Average vehicle trip duration (minutes)	57	72	64	40	31

The histogram below distributes routes into 10-minute time bands based on their average end-to-end running time. Uniquely numbered and operated are simply counted – as seen in the table above, some routes are far more important in terms of vehicle trips than others.

The figure is included here to validate the data within. For example, the most likely duration is 20-30 minutes, particularly for suburban routes. Suburban routes are (by definition) lower frequency but operate in territory where even headways are expected, so more likely to be optimised by schedulers to fit within a neat hourly cycle that, so for example, allows two buses to provide a half-hourly frequency.

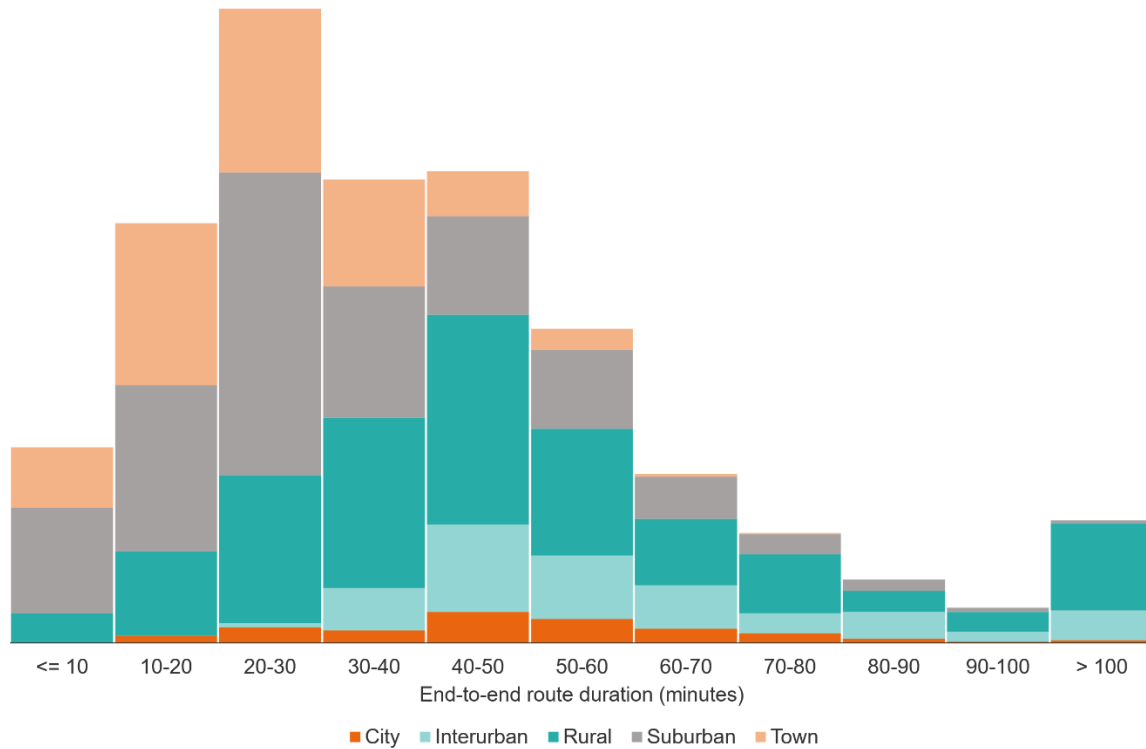


Figure 14: Distribution of route durations by archetype (unweighted for route importance)

The final figure in this section, below, shows vehicle trips by hour-of-day for each route archetype.

The peaks accord to school peaks – around 08:00 and 16:00. Notably these peaks do not occur on city services, which tend to be structured without significant daytime variation in headways. The greatest peaks occur on rural routes, territory where dependence on home-to-school transport tends to be greatest. Some of peaks observed will simply reflect existing local bus services where service level is emphasised to deal with scholar journeys – both additional vehicle trips and infrequent service headways retimed to suit school start or end times. Others will be contracted school-time only open services where there is a marginal benefit from registration (spares seats to sell to the public and Network Support Grant⁶⁸ to claim). There is no requirement to open school contracts by registering them as local bus services with a route numbers. Many operate as closed services, which are not available to the public, and so are outside the analysed dataset entirely.

⁶⁸ Network Support Grant, a per-mileage subsidy for local bus service operation, <https://www.transport.gov.scot/public-transport/buses/network-support-grant/>

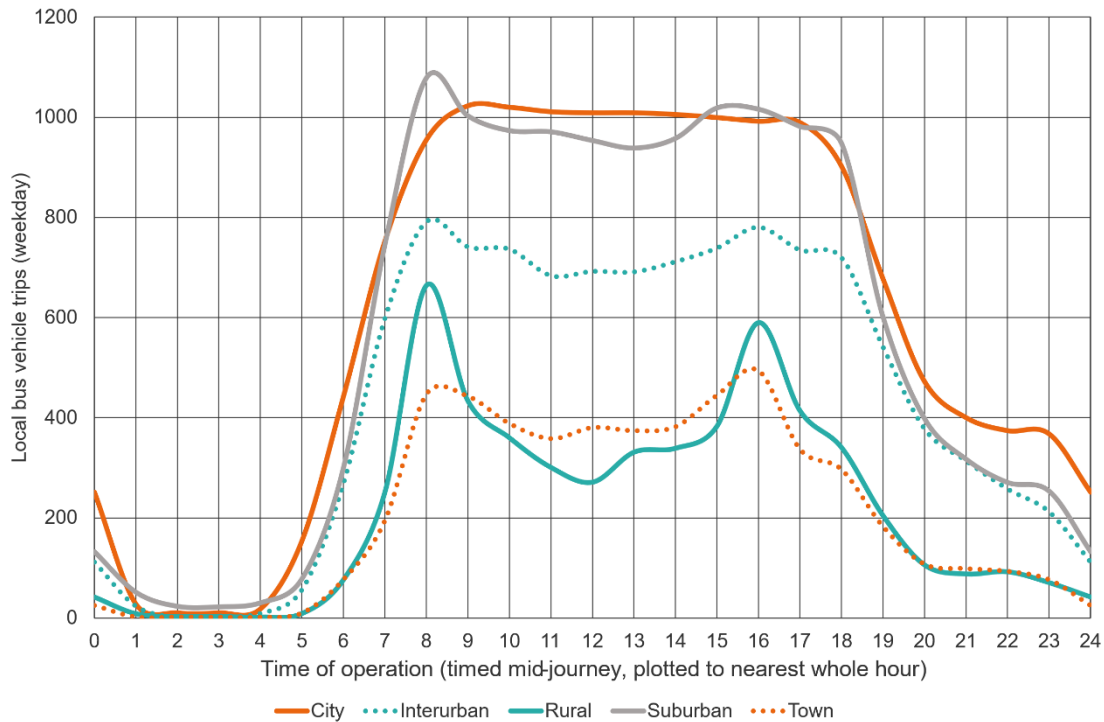


Figure 15: Scottish local bus vehicle trips operated by hour and archetype (weekdays)

The table below shows an example of how one bus changes both the operator and the typical route archetype on which it operates over one career. The route allocation shown here is based on manual examination of photographs taken across its career. The route number the bus is pictured operating has been cross-referenced to contemporary networks. Routes typically remain similar from year-to-year.

Table 6: Example - the routes of the Optare Solo registered “YP 02 LCA”

Year	Operator	Route archetype
2002	Connex Bus (London)	City
2007	Travel Wisharts (Angus)	interurban and rural
2011	Travel Dundee	Suburban
2015	JP Minicoaches (Forfar)	Rural and town
2017	JP Minicoaches	End-of-life (presumed scrapped)

6.4 Battery electric bus route compatibility

Assessment methodology

This section outlines the method and assumptions used to assess the likely compatibility of existing Scottish local bus routes to existing battery electric bus models.

The outputs of the route metrics analysis described in section 0 were used to estimate the total daily mileage of a bus travelling on a route for the full operational hours of that route. This was calculated as:

$$\begin{aligned} \text{Max daily mileage (km)} \\ &= \text{km per vehicle trip} \times \text{max no. of vehicle trips per bus day} \end{aligned}$$

Where,

$$\begin{aligned} \text{max no. of vehicle trips per bus per day} \\ &= \text{hours per day} \times \frac{60}{\text{Minutes per vehicle trip}} \end{aligned}$$

The kWh requirement for the bus per day was calculated by matching the average speed of the route with road type and fuel consumption data according to the following criteria:

Table 7 : Fuel consumption assumptions as a function of bus duty cycle

Road type / drive cycle	Average speed of route (km/h)	Energy consumption (kWh/km)
Inner city	14	0.977
Town suburban	25	0.910
Rural B roads	46	1.14
Rural A roads	63	1.13

The required power per bus per day was then compared to current BEB battery capacity. Routes were deemed compatible if the required kWh was less than the useable capacity of BEBs assuming a 20-80% depth of charge per day. For a 420 kWh battery, a route is compatible if the power requirement per day is less than 252 kWh.

Our method likely underestimates the number of incompatible routes for some categories, such as town and rural which are based outside cities. This is because it does not consider positional mileage⁶⁹ or additional demand on the battery from difficult terrain. It also doesn't consider inter-working of routes, where buses don't stay on the same route all day. Inter-working may either reduce⁷⁰ or increase⁷¹ the real-world overall daily mileage of the buses.

Estimated battery size requirement of route archetypes

Figure 16 shows the distribution of estimated battery size requirement across different route archetypes. This assumes charging of 20-80% on a typical day. As the Figure shows, the majority of city, suburban, town and rural routes can be served with a modest

⁶⁹ Distance that a bus needs to drive to get from the depot to the start of the route (and vice versa).

⁷⁰ Due to a bus spending some time on a less demanding route.

⁷¹ Particularly for rural routes that operate only a few hours per day, but where the bus is used for other purposes for the remainder of the day.

increase in battery capacity above the state-of-the-art offered today. Interurban services largely lie above the current market offer, with 11% of routes requiring 1 MWh or more battery capacity.

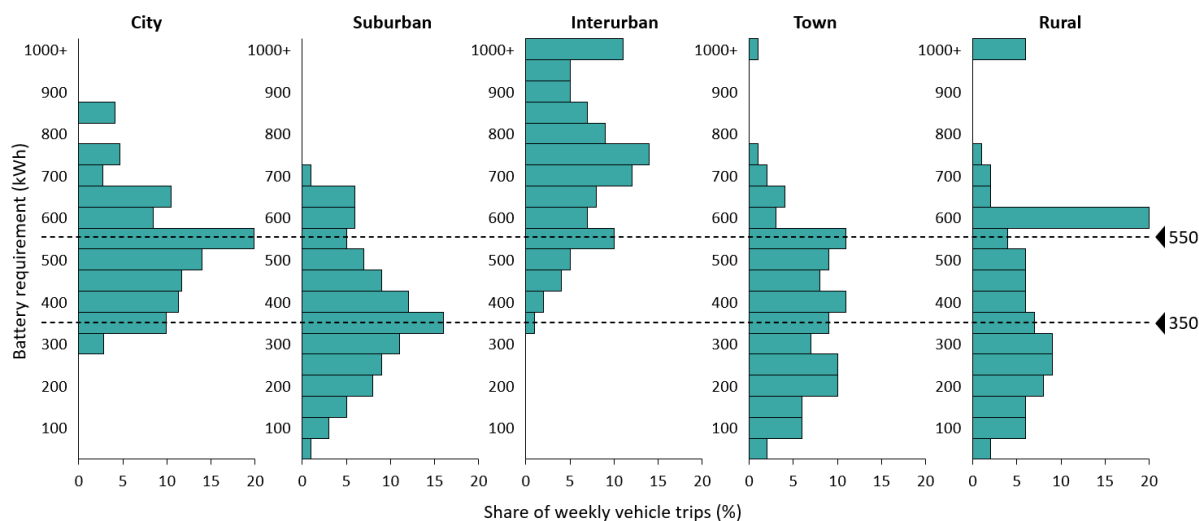


Figure 16 Distribution of estimated battery size requirement across route types, weighted by share of weekly vehicle trips.

6.5 Bus operator interviews

This section describes the approach we adopted to conducting operator interviews and lists participating organisations and individuals.

Approach to interviews

We interviewed a selection of Scottish bus operators as part of the study. The selection emphasised operators either with recent practical fleet electrification experience, or who had actively considered such. Interviews took the form of one-hour sessions to:

1. Confirm the operator's historic fleet and broad business model. This information validated the current market analysis and framed subsequent future-looking discussion.
2. Discuss both practical and strategic experiences of electrification and the issues arising.
3. Test what-if scenarios, to judge how operators might react to issues such as mismatch between vehicle capabilities and routes. Where relevant, operators were presented with the results of route suitability analysis for their network (described in section 6.4) as prompts for discussion.

In practise the interviews were semi-structured. Interviewees naturally skewed the conversation to those topics and issues most important to them and their business. Interviewee comments have been integrated into the main body of this report as broad, non-attributed commentaries on the important issues raised by interviewees. This is always true of topics where interviewees requested commercial confidence.

Organisations and interviewees are listed below.

CPT – Paul White (Scottish Director)

Industry body that represents most Scottish local bus operators. Introductory discussion.

First – Garry Birmingham (Decarbonisation Director)

Aberdeen-based multi-national group whose British bus business is the dominant local bus operator in both Aberdeen and Glasgow. Initial Scottish battery electric fleet now rapidly expanding. Glasgow's Caledonia depot is the largest bus recharging facility in the United Kingdom.

Lothian Buses – Sarah Boyd (Managing Director) and Dylan Dastey (Engineering Director)

Municipal operator, dominant in the city of Edinburgh, but also serving peri-urban territory in the Lothians. Has conducted several zero emission bus trials and is operating four double deck battery electric vehicles.

McGill – Ralph Roberts (Managing Director) and Russell Henderson (Engineering Director)

Emerging Scottish local bus operating group, primarily serving south-west Greater Glasgow, Dundee, and, via recent acquisition, Central (Stirling/Livingston) Scotland. Operating the largest battery electric bus fleet in Scotland.

Premier Coaches – Alan Findlater (Managing Director)

Small Aberdeenshire operator with a mix of group hire coach, non-local bus service school contracts, and oil industry staff contracts (especially since the Covid pandemic). About to take delivery of 10 battery electric minibuses for use on school contracts.

Whitelaw's – Sandra Whitelaw (Managing Director)

Small family operator, primarily of local bus services in peri-urban/rural South Lanarkshire. Parallel coach tour business has tilted toward school contract work since the Covid pandemic. Strong tradition of innovation and buying new, but unable to find a viable battery electric solution.

6.6 Battery electric buses currently available

Table 8 lists BEB models currently available in the British and Irish market, along with their key specifications.

Table 8: Currently available battery electric buses in Britain and Ireland (late 2022)

Type	Manufacturer name	Vehicle name	Battery size (kWh)	Driving range ⁷² (miles)
Single decker	Wrightbus	GB Kite electroliner	340 – 567	150-250
	BYD ADL	Enviro200EV	348	160
	Yutong	E10	422	<i>Not specified</i>
		E12	422	<i>Not specified</i>
	Volvo	7900e	198 – 389	<i>Not specified</i>
	Optare	Metrocity	<i>Not specified</i>	150-190
		Solo	<i>Not specified</i>	70-100
Double decker	Wrightbus	Streetdeck electroliner	340 – 454	200
	BYD ADL	Enviro400EV	339 – 382	160
Coach	Yutong	TCe12	281	200

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⁷² Driving range represents range quoted in manufacturer specification; real-world driving range may differ from that quoted.