Transport

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Case Studies in this section:

Challenge

Domestic transport rose from 16% to 29% of UK territorial emissions, from 1990 to 2023, and has been the single biggest source of the UK's territorial emissions since 2014[1]. Provisional statistics for 2024 put transport at 30% of total emissions[2], a rise of 1% on 2023[3].

Reliance on private cars generates high levels of congestion, contributes significantly to regional greenhouse gas (GHG) emissions, and worsens air quality. In the UK, 68% of roadside NO_2 concentrations in 2023 originated from NO_x emissions from exhaust pipes[4]. In South Yorkshire, 2023 roadside monitoring in parts of Rotherham recorded peak annual average NO_2 concentrations of over 60 µg/m^3, which is more than six times the World Health Organization (WHO) guideline of 10 µg/m^3. Additionally, Sheffield City Council estimates that road transport in Sheffield is the *"most-significant overall single contributor"* to NO_2 emissions, citing around a 30% share of NO_x from motor vehicles[5].

Although the transition to electric vehicles (EV) will mitigate tail-pipe emissions, indirect emissions associated with car manufacture and the current grid energy mix will still occur. Electric vehicles still produce particulate matter pollution from tyres and brakes, affecting local air quality and ecosystems. Moreover, the carbon payback takes significant time. Life-Cycle-Analysis (cradle-to-grave) of battery EVs (BEVs) concluded that a medium-size car would need to be driven for 70,000 km before embodied and operational emissions fall below those of a vehicle with an internal-combustion-engine[6]. Given that Sports Utility Vehicles (SUVs), which are larger than a medium car, represented 71% of new electric vehicle registrations (an increase since 2021 of 28%)[7], the carbon payback will be even more delayed.

The 'autobesity' trend has social and practical implications as well as environmental. SUVs cause more road damage, more congestion, increase parking pressure, and pose significant safety risks to those who walk, wheel and cycle[8]. More generally, the requirement for on-street EV charging facilities may directly conflict with space for active travel lanes and bike/e-cargo cycle storage, not to mention adding demand that could cause grid overloading during peak times. Furthermore, the uptake of EVs could exacerbate social and economic inequalities. Considering the relatively high cost of an EV, and the need for a space for plug-in charging, they are more likely to be purchased by higher income households with off-road parking. The benefits of EVs are therefore unevenly distributed, whereas the costs of upgrading the electricity network to cope with the additional demand will be added to everyone's bills.

This shows that the reliance on private cars and conventional delivery vehicles, particularly in dense, urban environments needs to be reduced. However, the number of licensed vehicles in the UK is rising; in December 2024, there were 2,605,000 vehicles registered for the first time, an increase of 3% from the year before[9]. South

1 Department for Transport (2025) Greenhouse gas emissions from transport in 2023.
2 DESNZ (2024) 2024 UK Provisional Greenhouse Gas Emissions.
3 Department for Transport (2025) Greenhouse gas emissions from transport in 2023.
4 DEFRA (2025) Emissions of air pollutants in the uk – nitrogen oxides (nox).
5 Ivings, S., King, J.A., Roocroft, A., Ortiz, P., Willis, T., Martin, M.V., Arbabi, H. and Punzo, G. (2025) Origin–destination specific traffic emissions and data-driven NO2 pollution-optimal routing in urban environments. Environmental Modelling & Software, p.106813.
6 Styring, P., Duckworth, E.L. and Platt, E.G. (2021). Synthetic Fuels in a Transport Transition: Fuels to Prevent a Transport Underclass. Frontiers in Energy Research, 9.
7 Transport Environment (2025) UK's SUV Surge is Driving Up Road Risk and Costs - will HM Treasury Act?
8 Ibid.
9 Department for Transport (2025) Vehicle licensing statistics, United Kingdom: 2024.

Yorkshire's population is also due to rise from 1.4 million in 2025 to over 1.55 million by 2043[10], which could potentially increase the number of cars and congestion, particularly around urban centres.

This growing pressure on South Yorkshire's roads could be relieved by modal shifts for short distance journeys to minimise traffic congestion and improve air quality. Growing population density should also be seen as an opportunity to increase the use and economic viability, of public and active transport, and its infrastructure, in Sheffield, Rotherham, Barnsley and Doncaster. In line with national trends, South Yorkshire's population is also ageing, which only increases the need for efficient and reliable public transport. The Leeds Observatory data predicts that the number of 70-84 year olds (data not available over 84) will increase from 149,998 (2018) to 211,889 (2043)[11].

However, there are significant challenges to achieving modal shifts. A SYSC study on the recent history of transport in the UK, discussed how 'motornormativity' (a concept developed by Ian Walker and colleagues[12]) emerged from specific post-war policy choices that entrenched car use in the built environment. This trajectory was not always certain. In the 1930s, the Ministry of Transport sought the creation of around 500 miles of cycle paths alongside road building, inspired by the cycle lanes being created alongside new roads in the Netherlands. During this period, more miles were cycled than driven, although this was reversed by 1950 and the gap has widened ever since. It is worth noting that Amsterdam's trajectory has been famously different and the gap has widened. While Amsterdam opposed the vision of streets existing mainly for cars[13], the same did not happen in the rest of the world, Britain included[14].

Motornormativity has in many ways locked systems into car use. Research conducted in 2023, explored cycling experiences over the life course of a group of Sheffield based cyclists. The results showed that one of the key changes over the

10 Leeds Observatory (n.d.) Population projections.
11 Ibid.
12 https://doi.org/10.1504/IJENVH.2023.135446
13 BICYCLE DUTCH (2019) The battle for the Ferdinand Bolstraat.
14 Reid, C. (2017). How the Dutch Really Got Their Cycleways. Bike Boom. Island Press, Washington, DC.

Transport Emissions

Domestic transport has been the ***single biggest source*** of the UK's territorial emissions since **2014**

Percentage of transport in UK territorial emissions

16% in 1990 → **29%** in 2023

Provisional statistics for 2024 show a rise of 1% to 30% total emissions

1% in 2024 ↑

past decades was a perception that safety was worsening. Bigger vehicles, driving faster, and at times more aggressively, have contributed to a difficult environment for cyclists (and pedestrians) to navigate[15]. This perception is supported by the statistics. Whilst the proportion of fatalities for car drivers is declining (from 52% in 2004 to 45% in 2023), it is rising for pedestrians (from 21% in 2004 to 25% in 2023) and pedal cyclists (from 21% in 2004 to 25% in 2023)[16].

Furthermore, the congestion and street parking in city centres presents challenges for running reliable bus services[17]. Mobility and safety are also key to creating a vibrant local economy. Transport for the North (TfTN) attributes the 25% gulf in Gross Value Added (GVA) between the North and other areas of England to *"sub-optimal transport links and underinvestment in transport"*[18]. Accessible public transportation is at the heart of equitable societies; residents having equal opportunity to travel when, where, and how they want, at affordable costs. Moreover, high quality, high connectivity transport networks support regional development and regional economic growth. To determine how accessible and affordable the current public transport (PT) system is in South Yorkshire, SYSC assessed regional job accessibility using the current PT network of South Yorkshire, taking 'communities' as populations within lower-layer super-output areas (LSOAs).

15 Parkes, S. and Rafalowicz-Campbell, M. (in preparation) Cycling past and present: an oral histories approach in Sheffield, UK.
16 Ibid.
17 Sheffield City Council (2024) Connecting Sheffield: Abbeydale Road and Ecclesall Road.
18 Transport for the North (2019) Northern Powerhouse: Independent Economic Review Core Messages.

Air Quality

Roadside monitoring in parts of Rotherham recorded peak annual average NO_2 concentrations of over

60 µg/m³

This is more than six times the World Health Organization guideline of

10 µg/m³

The study extracted three key metrics: (1) how many direct routes exist between all pairs of LSOAs; (2) modelled time spent travelling; and (3) minimum number of changes required to assess accessibility. It merged this analysis with SYSC's Energy Decadence project survey which provided five key outputs for this study: (1) age; (2) working status; (3) income; (4) education level, and; (5) whether or not respondents are struggling to pay for their transport bills.

We found that age was the most important predictor of transport affordability; younger people struggle to meet their transport bills significantly more than older people. Across South Yorkshire, our modelling predicted 32% of the total Barnsley region, 38% of the total Doncaster region, 35% of the total of Rotherham and 44% of the Sheffield region were struggling to pay for transport.

We also found that significant disparities emerge between those who rely on public transport and those with access to private vehicles. This is particularly true for those who don't live near high demand routes and/or work during 'off-peak' hours, often in low paid sectors such as warehouses and hospitals. The analysis shows that accessibility drops significantly during these shift-change windows.

Whilst public transport plays an important role in reducing GHG emissions and congestion as well as providing equitable access to workplaces, increasing active travel could play a significant role in improving public health (life expectancy for men and women in South Yorkshire is two years lower than the national average for England[19]), which also drives productivity. Still, care must be taken in the way that policies are designed to avoid a further entrenchment of motor-normativity and existing inequalities. For instance, a push to implement on-street EV charging infrastructure could affect pavement accessibility[20], hindering the government's targets for 50% of all the journeys to be completed via active travel methods such as walking, wheeling or cycling by 2030[21].

There is a need to uphold the rights of those who walk, run and wheel otherwise a 'green' EV policy may inadvertently entrench car use further. However, the EV transition also presents opportunities for community energy groups to co-own EV charging points so that financial benefits are retained locally, offsetting potential negative impacts and fostering a sense of local ownership.

19 NHS South Yorkshire (2025) A review of the health of South Yorkshire's population.
20 Possible (2023) Electric vehicle charging rollout poses growing threat to walking and wheeling targets and disabled access, warn charities.
21 Active Travel England (n.d.) About us.

Response

SYSC's research asked how we might build a more sustainable and equitable transport system that supports a thriving economy, society and environment. Whilst it is clear that private cars and vans will play a continued role in the transport systems of the future, it is only with fewer cars on the road, driving fewer miles, that we can deliver significant improvements in reducing carbon emissions whilst improving air quality, journey times and journey experiences.

The core question is how to facilitate modal shifts to active travel or public transport for a proportion of journeys. Traditional transport models often assume that travel time and monetary cost are the only determinants of modal choice[22]. In reality, a range of factors such as comfort, convenience, safety, and reliability are equally influential. Public transport users consider wait times and proximity to bus stops; active travel users are sensitive to hills, weather, and the availability of safe cycle routes.

SYSC is developing a decision-support tool that models the complex dynamics between factors that determine people's transport choices. The project seeks to understand the relationship between the enjoyability of a journey and the priority placed on the duration of the journey. The hypothesis posits that when a person's experience of moving is higher quality, they place a lower priority on time taken (within reason). An increasing positive experience of different travel modes helps broaden a person's alternative modal choice and increases the likelihood that they will select an alternative form of transport to the private vehicle.

Using the tool, it will be possible to pinpoint specific roads and routes where current conditions and traffic patterns already create a high probability that people will choose walking or cycling over driving. This shows us where the shift away from cars is already most likely to happen based on the real-world behaviour of the traffic network. Once the tool has been optimised, the project team will produce a series of scenarios tailored to regional priorities, such as:

- Shifting commuting trips from cars to public transport through service frequency improvements.

22 McFadden, D. (1974), 'The measurement of urban travel demand'. In: A. A. P. D. Hensher and P. R. Stopher (eds.), Behavioural Travel Demand Modelling. Lexington Books, pp. 279–318

- Designing active travel corridors between key employment centres and residential areas.
- Testing the impacts of low-traffic zones or car-free city centre policies.

There is also a need to explore opportunities for modal shifts from commercial delivery vans. SYSC funded interdisciplinary research to investigate the technical viability for e-cargo cycle deliveries across South Yorkshire as well as the socio-economic barriers to their adoption.

A modelling exercise found that there is great potential for e-cargo cycles to replace a significant proportion of last-mile deliveries in South Yorkshire's urban areas, especially where there is a high density of businesses and housing. Feasibility was found to be particularly high in Barnsley and Rotherham; across the areas of 80 km$_2$, e-cargo cycles still take less time than vans, despite making a mean of 5.9 and 6.2 subtours (between which more packages are picked up from the depot). In Sheffield, e-cargo cycles outperformed vans no matter the number of stops when the delivery area was 16km2 or less. In Doncaster, feasibility is high for e-cargo cycles up to 12 stops but is always outperformed by a van after 26 stops. This is due to lower business density and faster arterial routes that favour vans.

Whilst the modelling demonstrated strong potential for e-cargo cycle deployment, the accompanying qualitative research found significant challenges such as business resistance to change, the safety and security of both riders and e-cargo cycles, as well as a lack of local authority resources to support the transition. However, a clear role for local government emerged, alongside continued commitment to invest in cycling infrastructure; supporting the normalisation of e-cargo cycles through trials and their incorporation into internal fleets , with one interviewee noting *"People are not going to start seeing this as an alternative unless they start seeing them"*.

The combined study shows that there are strong use cases for Small and Medium-sized Enterprises (SMEs) and for certain delivery types (i.e. small parcels, groceries, medicines, documents). There could be additional value for those positioning themselves as sustainable businesses to their customers. Larger companies may also find value in partial adoption, with e-cargo cycles complementing vans for some types of deliveries.

Equitable Transport

Transport for the North attributes the **25% gulf in Gross Value Added** between the North and other areas of England to **"sub-optimal transport links and underinvestment in transport"**

Across South Yorkshire, our modelling predicted that

32% of Barnsley residents

35% of Rotherham residents

38% of Doncaster residents

44% of Sheffield residents

were struggling to pay for transport

This could reduce congestion pressure and improve air quality in dense urban areas.

Whilst some journeys can and should be shifted to alternative modes of transport, motorised vehicles will remain a significant part of the transport system. Therefore, policy and technical innovation is needed to temper the social and environmental costs associated with private and commercial motorised vehicles.

Researchers at The University of Sheffield found that re-routing vehicle traffic using a pollution-optimal traffic assignment model (TA) can reduce congestion and achieve a 21% reduction in Sheffield-wide NO_2 concentrations, reducing the number of roads exceeding WHO recommended limits from 37% to 30%. Traffic re-assignment could also reduce the number of roads exceeding 20μg/m3 - a level associated with elevated long-term health risks[23] - from 8% to 5%. Moreover, these gains are not accompanied by significant time penalties for drivers - the average increase in journey times is just ~20 seconds showing that health and environmental benefits don't need to come at the cost of major inconvenience.

Regional traffic policies may be implemented to encourage drivers to take the pollution-optimal routings. However, the transition to EVs will present new air pollution challenges; Particulate matter (PM) 10 and 2.5 from road, brake and tyre wear will increase due to the increased weight of EVs (compared to conventional vehicles) caused by large batteries[24], although advances in regenerative braking may eventually reduce pollution[25].

23 WHO (2021) WHO Global Air Quality Guidelines: Particulate matter (PM2.5 and PM10), ozone, nitrogen dioxide, sulfur dioxide and carbon monoxide, World Health Organization, Geneva.
24 Parkes, S. and Rafalowicz-Campbell, M. (in preparation) Cycling past and present: an oral histories approach in Sheffield, UK.
25 Liu, Y., Chen, H., Gao, J., Li, Y., Dave, K., Chen, J., Federici, M. and Perricone, G. (2021). Comparative analysis of non-exhaust airborne particles from electric and internal combustion engine vehicles. Journal of Hazardous Materials, 420(126626), p.126626.

Transport Recommendations for Regional Policymakers

1. Working in collaboration with researchers, businesses and communities, local policymakers should include **communication and engagement campaigns that actively tackle 'motor-normativity'** in their delivery plans for promoting public and active transport. This should include creating **explicit statements of the benefits of multi-modal transport** in order to build public understanding of, and acceptance for, the need for change.
2. Planning departments should **change their focus from the optimisation of the flow of vehicles to the flow of people**, to give greater priority to alternative modes of transport that could deliver a more sustainable transport system, as well as a better experience for South Yorkshire's residents.
3. Acknowledging that transport-related economic and social exclusion limits regional growth ambitions, **local policymakers should use the transition to public control of buses by 2027 to implement an equity-based approach to service provision (in contrast to demand-driven models). This should occur alongside the introduction of a simplified distance-based fare structure** that eliminates the financial penalty of transferring between services.
   i. South Yorkshire's Public Transport Network and Distributive justice: Which Communities Face Poor Job Opportunities?

2. SYSC research has shown high feasibility for e-cargo cycles to replace last-mile deliveries in South Yorkshire's urban centres. **Local policymakers should work collaboratively with potential local providers** (such as a Different Gear, Evoloce or Russell's Bicycle Shed (all Sheffield based)) **to create a coherent, resourced, South-Yorkshire-wide e-cargo cycles scheme** that provides: a try-before-you-buy fleet, business change support, and support accessing subsidies and grants. In parallel, investment is needed in infrastructure such as sufficiently wide, segregated lanes, strategically placed distribution hubs and parking and storage facilities.
   i. Modelling the Impact of e-cargo Bikes for Last Mile Deliveries in South Yorkshire.
   ii. E-cargo Cycle Schemes: Lessons for Policy Design.
3. Regional transport planners should **include air quality as a design factor when developing local traffic policies** (i.e. speed limits or traffic light timings) as pollution optimal routing could reduce NO2 concentrations on major roads without significant increases to journey times (~20 seconds).
   i. Improving Air Quality: Re-Routing Sheffield's Commuting Cars Could Reduce City-Wide NO2 Concentrations by 21%.

Further Research Opportunities

The impact of EV charging infrastructure on urban spaces and accessibility, particularly conflict with walking, wheeling and cycling.

Factors influencing EV adoption beyond charging infrastructure - such as cost, range anxiety, vehicle choice, sensory (i.e. sound and feel of a petrol or diesel engine).

Best practices for integrating active travel, public transport, and EV use.

Effectiveness of various nudging techniques to promote sustainable transport.

The impact of urban planning and policy on travel behaviour and mode shift.

Research to understand the potential for regional policies to accelerate EV adoption.





Improving Air Quality: Re-Routing Sheffield’s Commuting Cars Could Reduce City-Wide NO_2 Concentrations by 21%

Project team:
University of Sheffield: Samantha Ivings, Dr James A. King, Dr Alexander Roocroft, Dr Patricio Ortiz, Toby Willis, Dr Maria Val Martin, Dr Hadi Arbabi, Dr Giuliano Punzo

Challenge Statement

In the UK, roadside nitrogen dioxide (NO_2) - a pollutant closely linked to vehicle emissions - often exceeds recommended levels, contributing to respiratory issues and broader health inequalities. In 2023, 68% of UK roadside NO_2 concentrations originated from car exhaust pipes[1]. Black-box data from 2019 records an average daily traffic volume in Sheffield of 15,898 private cars per hour commuting during peak hours: weekdays 7-9am, and 4-7pm[2]. Sheffield’s air quality is worsened by NO_2 during busy hours where traffic is congested - as stop/start traffic leads to more NO_2 output[3] - and due to under-utilisation of high-capacity roads. Therefore, by optimally re-routing traffic between origin and destination, it may be possible to improve local air quality even without reducing the number of cars on the road.

Research Response

To understand how best to re-route Sheffield’s commuters, we developed a traffic assignment (TA) model, a tool predicting how vehicles moving between their origins and destinations (OD) will distribute on the road network. When paired with emission models, TA models allow the assessment of road-specific environmental impacts, providing critical information into the relationship between traffic distribution and air pollution.

The study develops a data-driven pollution function that calculates the direct relationship between traffic density and NO_2 levels. We have integrated three distinct datasets[4] so that we can optimise vehicle routing to reduce emissions without needing to change infrastructure or public transit habits.

While the method developed is applicable to any road network, the goal of this work is to provide a quantitatively robust strategy for minimising car-associated NO_2 pollution across Sheffield, allowing more roadsides to fall within acceptable NO_2 guidelines provided by the World Health Organisation (WHO).

1 DEFRA (2025) Emissions of air pollutants in the uk – nitrogen oxides (nox)
2 The Floow (an Otonomo Company). Smart mobility observatory, 2023.
3 Zhang, K., Batterman S., and Dion F. (2011), ‘Vehicle emissions in congestion: Comparison of work zone, rush hour and free-flow conditions’. Atmospheric Environment, 45(11):1929–1939.
4 (1) traffic data gathered by the Sheffield City Council (SCC); (2) environmental sensor data from the Sheffield Urban Flows Observatory (SUFO); (3) readings from the Sheffield Hallam Athletics Stadium Weather Station.

Evidence and Outputs

To understand how people currently route their journeys between OD pairs, we assume road users will choose the fastest possible route for themselves (Sheffi, 1985). Thus, we create a TA model that is time-optimal for each individual user (i.e. minimising individual travel time). This is regarded as the current mobility scenario. We compare this with our TA model that is pollution-optimal city-wide (i.e. minimising overall NO_2). Many results arise from comparing these two scenarios.

The road-wise changes in traffic flows required to move from the current to the pollution-optimal

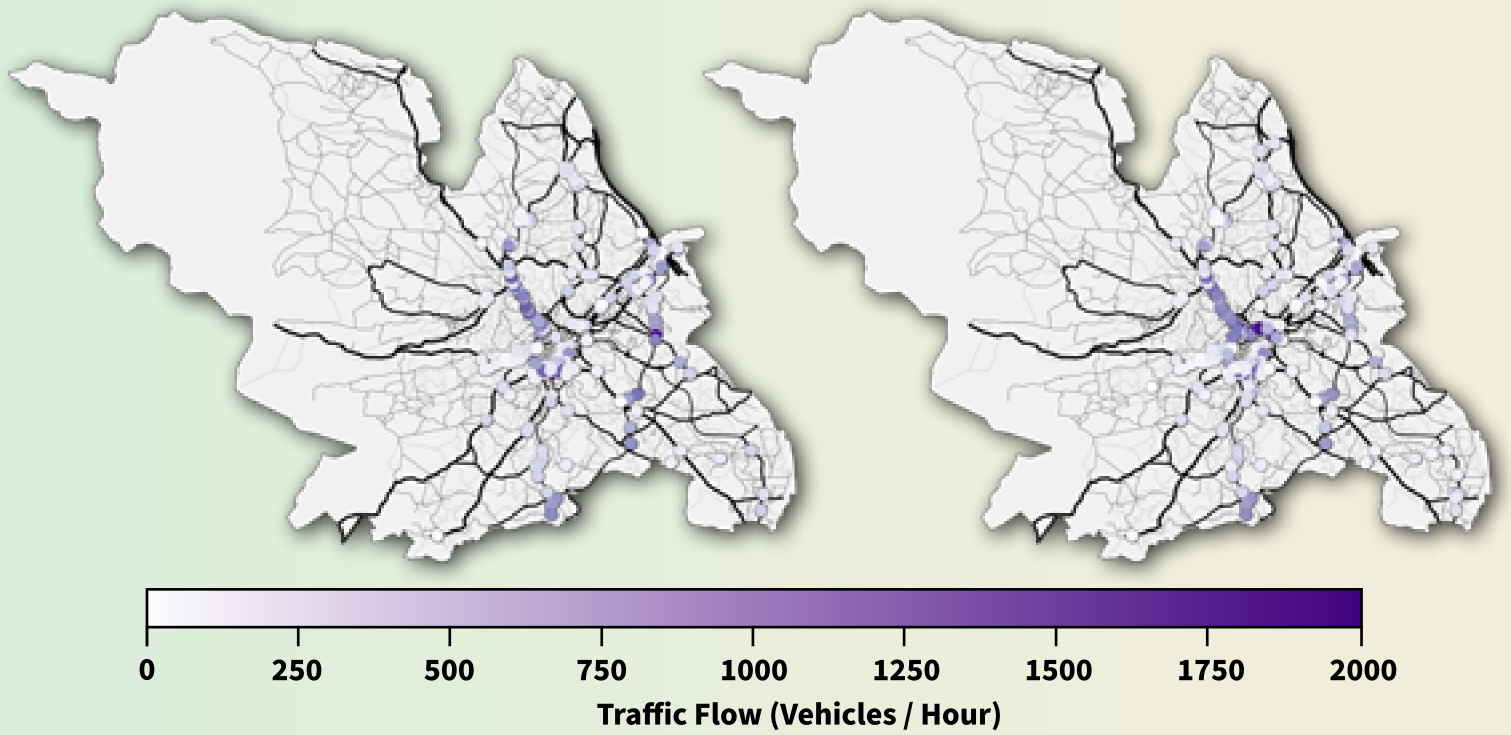

Figure 1 (a and b): Traffic flows during 2019 and 2023 in Sheffield, UK. Measurements are from Sheffield City Council traffic sensors. Plots show hourly averages across peak times (7-9am, 4-7pm) for Feb - Oct of each year.

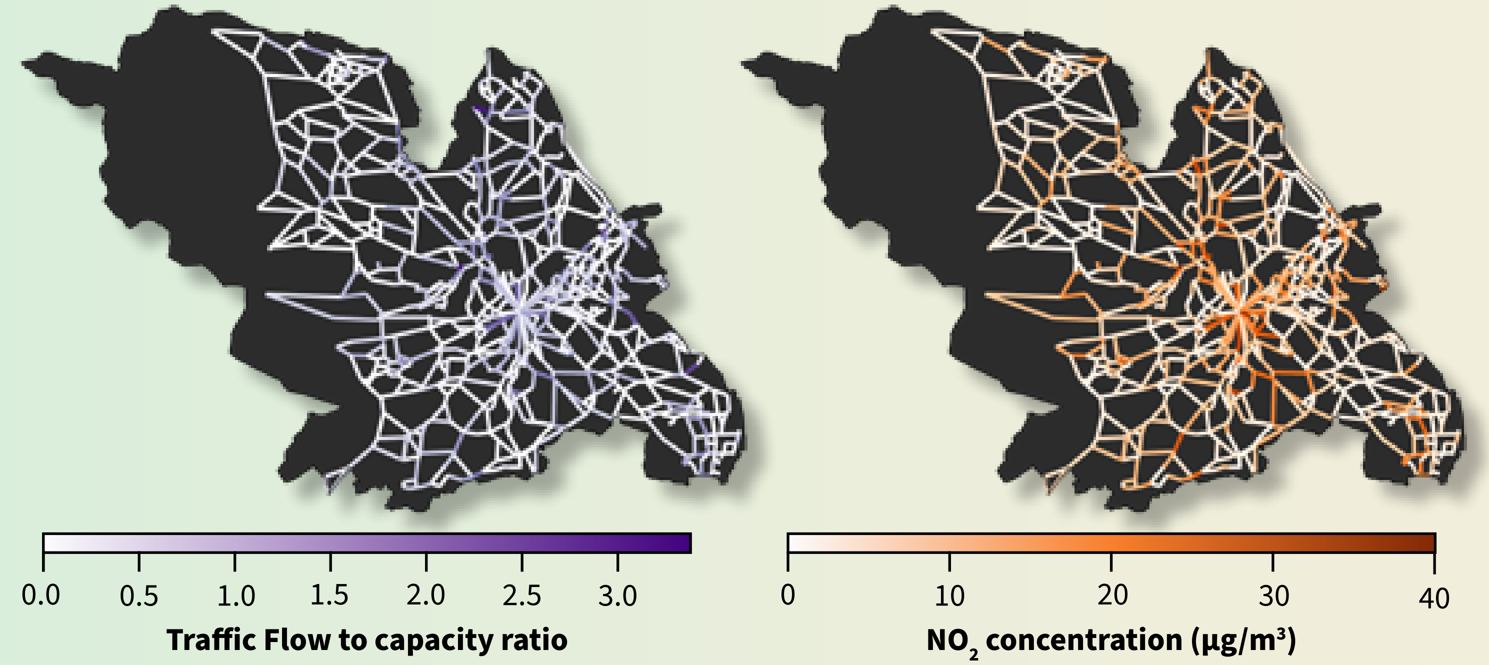

Figure 2 (a and b): Road-wise TA outputs for the current transport scenario in Sheffield, from Feb - Oct 2019 during peak hour.

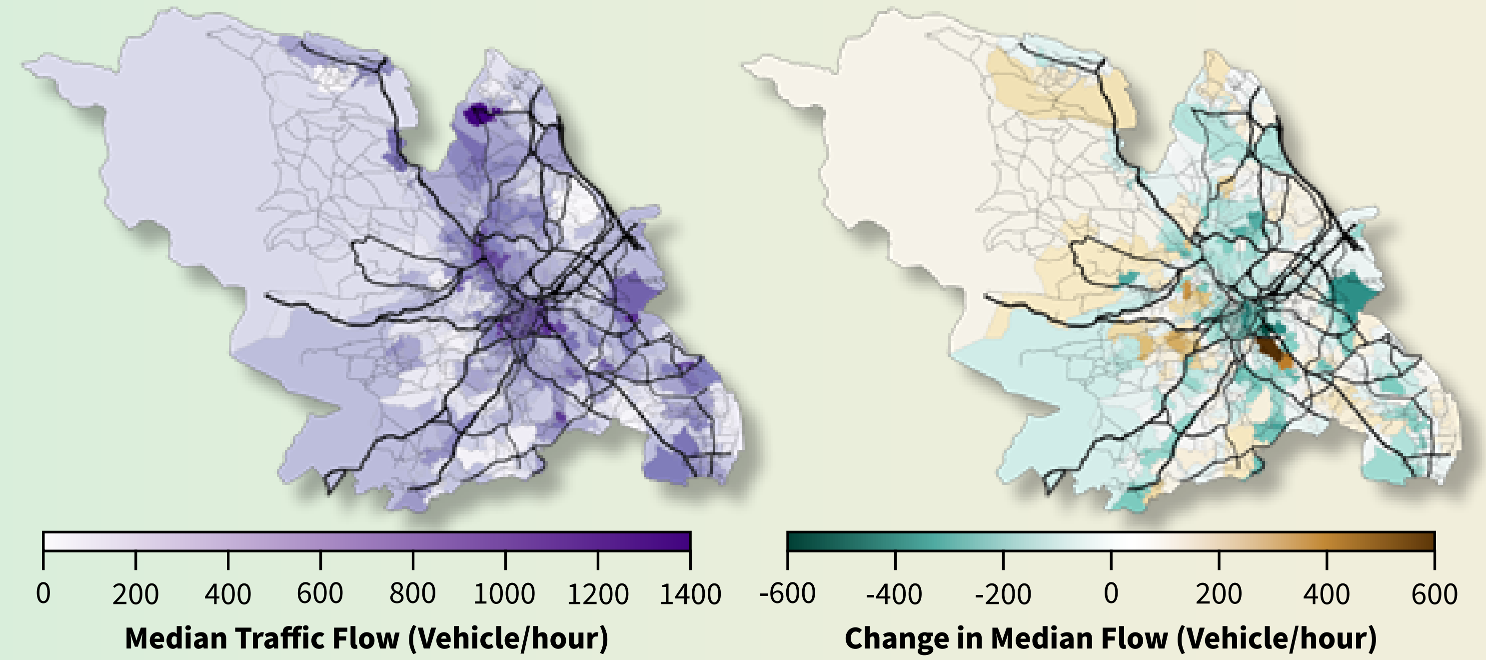

Figure 3 (a and b): LSOA-aggregated traffic flow results from two TA models: the current scenario, and the pollution-optimal. For each LSOA, the median road is visualised.

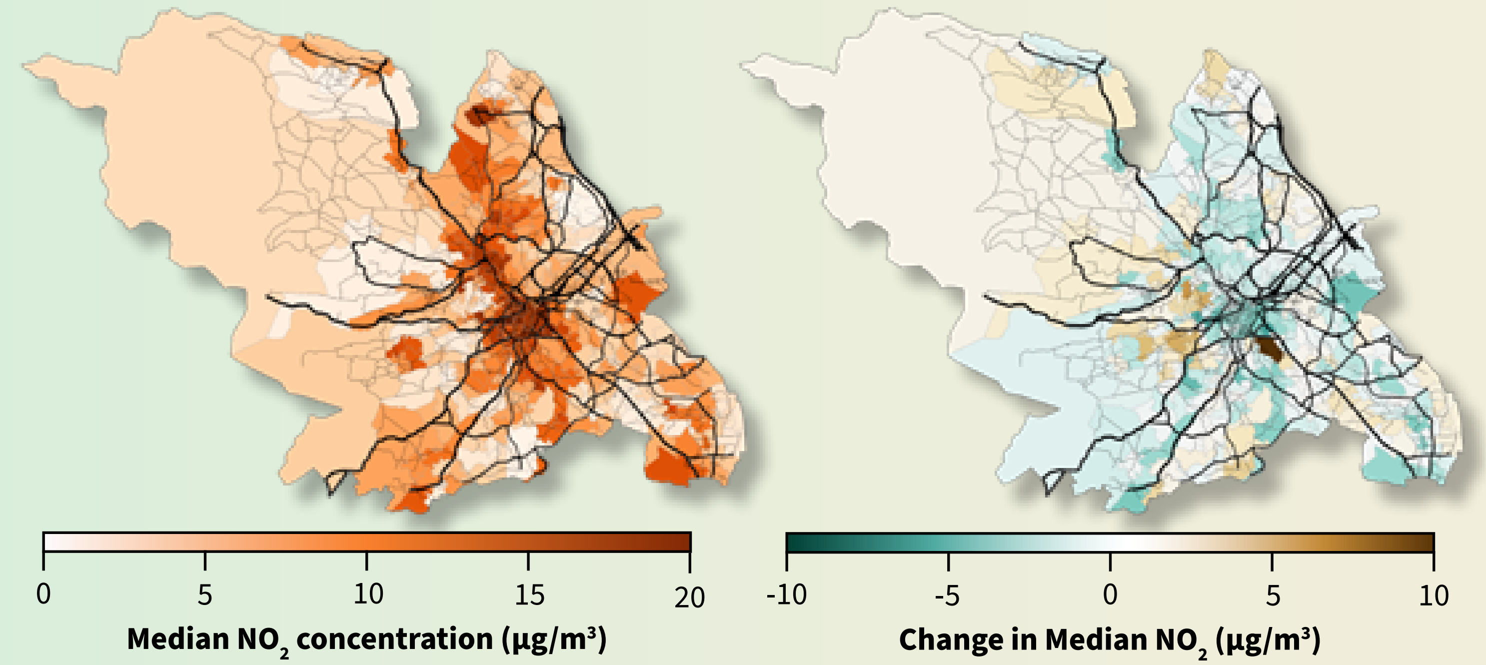

Figure 4 (a and b): LSOA-aggregated NO_2 concentration results from two TA models: the current scenario, and the pollution-optimal. The median road per LSOA is shown.

scenario is shown in Figure 2. In total, 981 roads (45.4%) require flow reduction, 1,039 (48.1%) require an increase, and 140 (6.5%) require negligible - i.e., modelled as zero - change to flows. Under pollution-optimal routing, increased traffic flows are assigned to major roads such as Barnsley Road, Firth Park Road, and Penistone Road. Meanwhile, roads within the same region as these, yet of a lower road class, require less flow.

In the current scenario, our TA output shows that flows on 671 (31.1%) of roads exceed their capacity, hence becoming congested. Many of these roads are situated at the city centre, extending through major arterial routes connecting the centre to the Northwest, Northeast, and Southern areas of the city in particular. In the pollution-optimal case, only 499 (23.1%) of roads exceed flow capacity: the city centre and the high-flow route towards the upper East of the city still experience congested roads, though the number of these is reduced. On average, roads in the current scenario are operating at around 71% capacity. In the pollution-optimal scenario, this figure is 69%, showing that minimising NO_2 concentrations desirably does not increase network-wide traffic congestion through flow management.

Roads modelled as currently having the highest flows - and highest NO_2 concentrations - are situated within and around the city centre, diminishing towards the West of the city. Much of the East shows low flow/NO_2, with the exception of very high results on the upper East route.

We have aggregated our road-based results to a Lower Layer Super Output Area (LSOA). The median road in each LSOA is reported. It is worth noting that LSOAs with very few roads passing through them may take a higher number of vehicles compared to those with high road counts.

[Click here to open an interactive LSOA map for Sheffield in 2019 (HTML)]; Sheffield train station is marked with a red dot.

For the current mobility scenario, Figure 3(a) shows the median road's traffic flows within each of Sheffield's LSOAs. Several of the highest-flow LSOAs are situated around Sheffield's train station slightly East of the centre (such as Arbourthorne and Park Hill & Wybourn), with high flows also in directly bordering regions. Moving away from the centre, elevated flows remain along major arterial roads; particularly those connecting the North and East of the city with the centre.

In terms of commuting routes, we see that a route with some of the heaviest traffic flows in the current scenario is associated with commuting to/from the East of Sheffield towards both Rotherham and, further afield, Doncaster. Moreover, this route is situated very close to both Meadowhall and the Northern General Hospital. The highest flow LSOA along this route is an industrial area (company count 1,676, population 1,872), while other high-flow LSOAs are residential. These results suggest that residential LSOAs, located near major roads connecting industrial zones, are most impacted pollution-wise by through-traffic.

Shifting to a pollution-optimal case (Figure 3(b)), we find that the industrial district between Sheffield and Rotherham would see an increase of traffic away from the shortest route between the origin and destination, distributed instead along currently low-flow roads. Increased flows appear to facilitate flow reductions in neighbouring regions.

All of the ten highest-flow LSOAs in the pollution-optimal scenario would see lower median flows compared to the current scenario, achieving a 28% reduction. Across the whole network, an 8% total reduction in median road flows can be attained. This shows a redistribution of vehicles away from busy roads where traffic re-routing is feasible.

The analysis comparing the current (time-optimal) against the pollution-optimal routing scenario returns an Environmental Price of Anarchy (EPoA)[5]. This means that individual, self-interested behaviour results in higher environmental costs than socially optimal, centrally organised systems; in this case, selfish time-based routings are found to be 21% more environmentally costly than the pollution-optimal routings.

Figure 4(a) shows the median NO_2 concentration per road within each LSOA for the current scenario. As expected from the modelled traffic flow counts, the highest NO_2 concentrations are found in and around the city centre, and generally coincide with the highest traffic flows. Elevated concentrations are especially prominent along spatially connected North-South corridors and intersecting the centre. Some regions in the South, not experiencing excessive traffic flows, also show elevated NO_2 concentrations. This is likely due to the associated

5 Koutsoupias, E. and Papadimitriou, C. (2009), 'Worst-case equilibria', Computer science review, 3(2), 65–69.

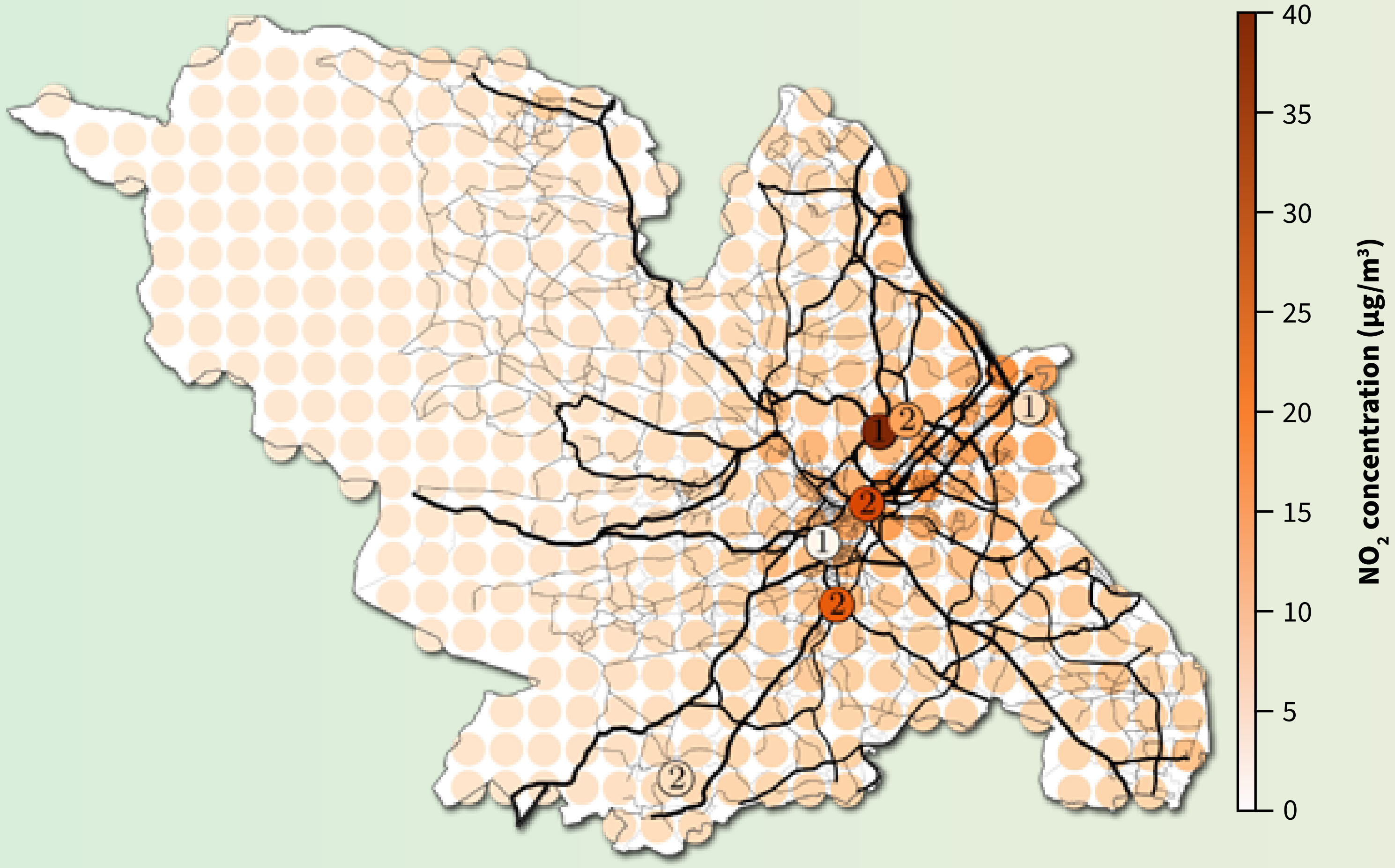

Figure 5: NO_2 concentration levels during 2023 in Sheffield, UK. City-wide background NO_2 concentrations are modelled by DEFRA, provided as hourly averages across 2023. Points labelled with (1) show measurements from Sheffield City Council (SCC) sensor datasets, averaged hourly across peak times (7-9am, 4-7pm) for Feb - Oct 2023, with NO_2 measurements provided in the unit µg/m3. Points labelled with (2) show additional SCC sensor readings, averaged hourly across the same time frame, with NO_2 measurements provided in the unit parts per billion (ppb). These measurements in ppb were then converted to µg/m3 using the ideal gas law.

roads operating near or above their saturation rate (flow/capacity), leading to high air pollutant outputs.

Figure 4(b) shows the difference in modelled NO_2 concentrations per LSOA between the current and the pollution-optimal scenario. We find that 204 LSOAs (59%) experience a reduction in median NO_2 concentration under pollution-optimal routing, while 141 LSOAs (41%) see an increase. Although some regions in the city show modest increases in NO_2, the largest air quality improvements are observed within the currently most polluted LSOAs. Conversely, some of the increases occur in low-pollution LSOAs, suggesting a re-distribution of pollution that results in a more balanced spatial distribution of NO_2 across the city.

Finally, using data from a University of Sheffield's Urban Flows Observatory automatic number plate recognition camera during Feb-Oct 2023, we found that, with the current fleet composition, passenger car flow alone predicted over 88% of the variation in NO_2 levels, even though features such as fuel type and vehicle age were accounted for.

What does this mean for the region?

By taking pollution-optimal routings, a 21% reduction in city-wide NO_2 concentrations could be achieved. These changes in NO_2 concentrations have significant implications for public health. Under the current traffic scenario, 37% of roads in the network are modelled to exceed the WHO annual mean guideline of 10µg/m3 during peak hours. In the pollution-optimal scenario, this proportion falls to 30%.

Additionally, the proportion of roads exceeding 20µg/m3 - a level associated with elevated long-term health risks[6] - declines from 8% to 5%. These results suggest that optimal traffic re-routing can meaningfully reduce population exposure to harmful levels of air pollution. Our model especially reduces pollution within areas currently experiencing high NO_2 levels, such as along the route connecting the city centre to the Upper East of Sheffield, such as Burngreave and Tinsley & Carbrook.

In terms of road user satisfaction, these cleaner routes only add an average of ~20 seconds per journey (9% higher than in the current scenario), suggesting that health and environment benefits don't need to come at the cost of major inconvenience.

Local traffic policies may be implemented to encourage drivers to take the pollution-optimal routings, such as adapting speed limits on major roads where some increase of traffic is recommended, and/or altering the timings of traffic lights. As passenger car flow emerges as the main NO_2 predictor, promoting strategies to reduce car usage may be the single most effective action to consider.

Next steps

This study used a constant level of background NO_2. To further understand the spatial distribution of NO_2 across the city, we could apply a varying background level dependent on location to improve the accuracy of the model (see Figure 5). In this study Sheffield's Clean Air Zone (CAZ) and its implications were outside of scope. Further research could investigate the traffic flow rates within CAZ and its effectiveness and potential improvements to reduce air pollution.

This study could also be replicated for the remaining metropolitan areas in South Yorkshire to understand the opportunities for improving air quality through pollution-optimal traffic routing.

Finally, while our results suggest that the flow of private cars is the main contributor to NO_2, these are based on the current fleet composition, which the introduction of electric vehicles is quickly modifying. A refined analysis would then be needed to consolidate this output.

6 WHO (2021) WHO Global Air Quality Guidelines: Particulate matter (PM2.5 and PM10), ozone, nitrogen dioxide, sulfur dioxide and carbon monoxide, World Health Organization, Geneva.

Cleaner Journeys, Smarter Cities: A Multi-Layer Transport Model for Optimised Modal Shifts in South Yorkshire

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Challenge Statement

Reliance on private cars generates high levels of congestion, contributes significantly to regional greenhouse gas (GHG) emissions, and worsens air quality. The South Yorkshire Mayoral Combined Authority (SYMCA) has set ambitious goals for decarbonisation and modal shift[1], but there is a gap in the policy makers' toolkit for a model that integrates both the technical and psychological factors influencing how people choose to travel.

Traditional transport models often assume that travel time and monetary cost are the only determinants of modal choice[2]. In reality, factors such as comfort, convenience, safety, and reliability are equally influential[3,4]. Public transport users consider wait times and proximity to bus stops; active travel users are sensitive to hills, weather, and the availability of safe cycle routes[5,6]. Without capturing these nuances, regional planning risks underestimating both the barriers and opportunities for a shift away from private cars.

Research Response

We aimed to address this challenge by developing a decision-support tool that combines technical modelling with behavioural insights. Working in close collaboration with Professor Andrés Medaglia's research group at Universidad de los Andes in Bogotá, we drew on their expertise in system dynamics and decision science. Their team brought international experience of designing participatory approaches to transport modelling, which was central to our project's success.

Our work directly engaged with South Yorkshire stakeholders. On Tuesday 18 November 2025, a workshop took place in Sheffield with local transport experts, businesses, community representatives, and policy makers. This workshop, co-designed by the researchers in Sheffield and Bogotá, captured diverse perspectives on the most important factors shaping modal choice, such as travel time, economic cost, comfort, and safety. The workshop was followed by a four-day programme of in-depth interviews, led by the Bogotá researchers. These interviews provided a deeper understanding of the psychological and social drivers of travel behaviour, ensuring that our modelling reflects lived realities as well as technical constraints.

From these activities, we co-developed a Causal Loop Diagram that identifies the "unifying cost" people care about when deciding whether to drive, take the bus, walk, or cycle. This could be framed in terms of time, money, safety, or a combination of these. These insights will then be translated into empirically-informed cost functions that underpin a multi-layer traffic assignment model.

We began with the physical number of cars on the streets. When this volume of vehicles exceeds the roads' capacity, we experience congestion, slower speeds and lengthier journeys. This can drive a shift toward active transport trips, where people choose to walk or cycle rather than rely on vehicles. This change in behavior typically increases journey enjoyment, reflecting the personal satisfaction or pleasure felt while traveling. As someone enjoys their trip more, their opportunity cost of travel time - the priority they place on minimizing every minute of their commute - starts to feel lower because of the time spent moving being seen as higher quality.

An increasing positive experience of different travel modes helps broaden a person's alternative modal choice. This is their experience of having the freedom and practical ability to choose between different ways to get around. As these alternatives become more viable, we see a drop in car trips and an increased choice for public transport options in proportion of total travellers. A reduction in these car trips eventually leads to fewer vehicles on the road easing the initial congestion and closing the loop.

This model allows us to redistribute South Yorkshire's current origin–destination (OD) demand, currently dominated by private cars, across other transport networks, including public

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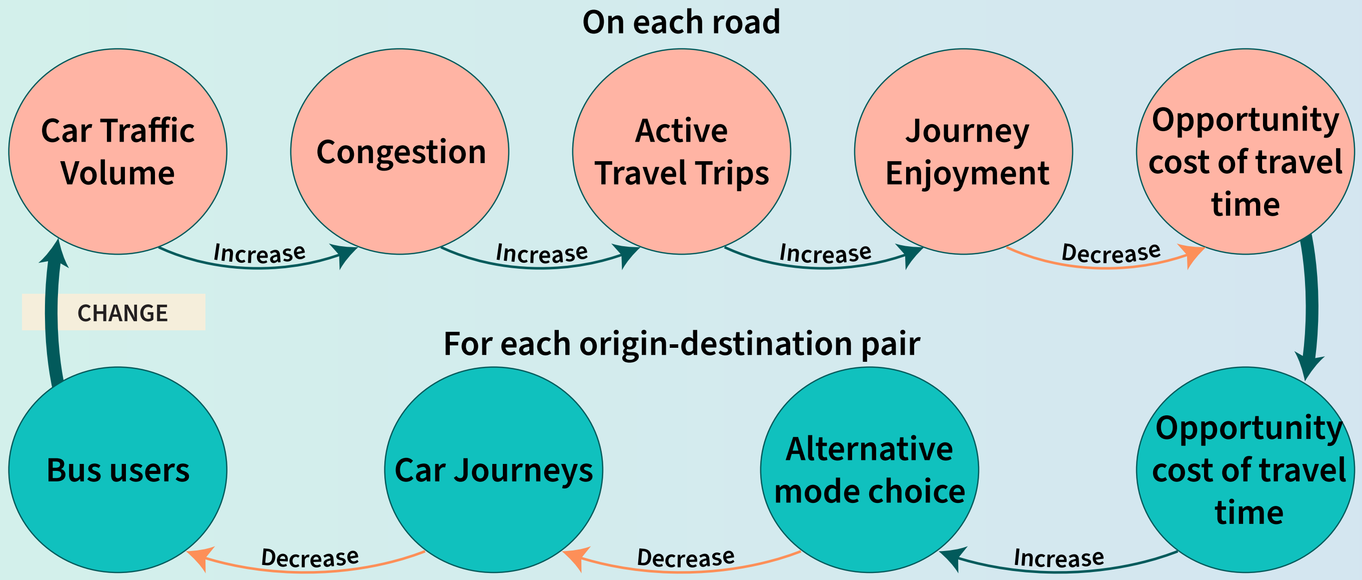
1 SYMCA (2022) South Yorkshire Mayoral Combined Authority Energy Strategy
2 McFadden, D. (1974), 'The measurement of urban travel demand'. In: A. A. P. D. Hensher and P. R. Stopher (eds.), Behavioural Travel Demand Modelling. Lexington Books, pp. 279–318.
3 Beirão, G. and Sarsfield Cabral, J. A. (2007), 'Understanding attitudes towards public transport and private car: A qualitative study'. Transport Policy, 14(6), pp. 478–489.
4 Redman, L., Friman, M., Gärling, T., and Hartig, T. (2013), 'Quality attributes of public transport that attract car users: A research review'. Transport Policy, 25, pp. 119–127.
5 Ibid.
6 Pucher, J. and Buehler, R. (2008), 'Making cycling irresistible: Lessons from the Netherlands, Denmark and Germany'. Transport Reviews, 28(4), pp. 495–528

Multi-layer transport model for South Yorkshire



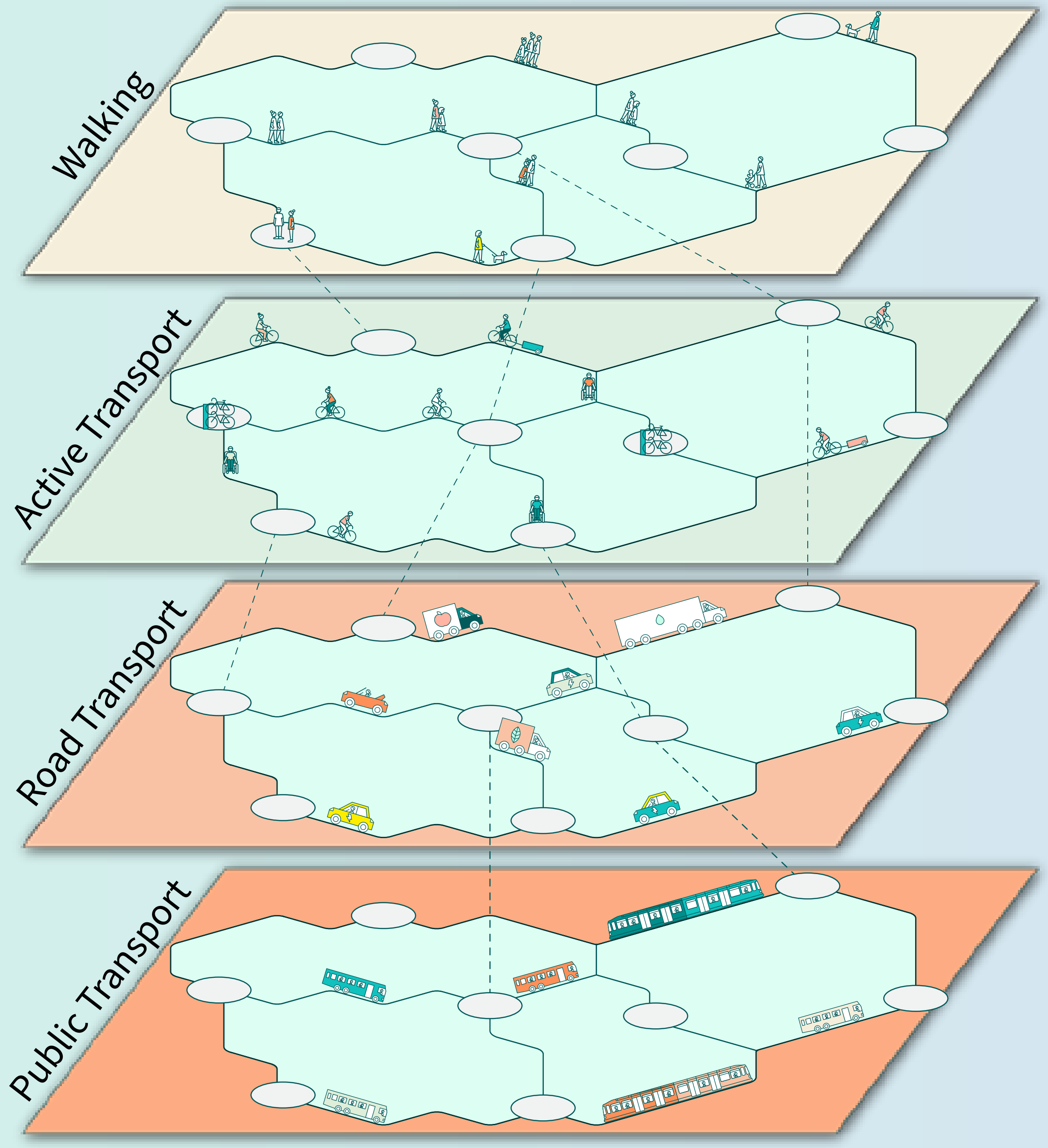


Figure 1: Simplified road network for South Yorkshire showing origin-destination active travel likelihood.

transport and active travel. Importantly, the model is not limited to time efficiency but incorporates the broader factors stakeholders identify as decisive. We refer to it as multilayer, as it deals with congestion at a road by road level and with mode preference at end-to-end journey level.

Evidence and Outputs

While full results are still in development, our approach is already producing tangible outputs. We are building a base case using Sheffield 2019 OD data from The Floow, which we will then scale to the entire South Yorkshire region. By integrating stakeholder-informed "cost functions" putting numbers to the causal relationships above, we will be able to simulate how journeys could shift from private cars to other modes under different policy scenarios.

The model can generate actionable insights, for example:

- Identify where public transport improvements (such as doubling bus frequency on main commuter corridors) are most likely to attract former car users.
- Highlight urban routes where the introduction of safe cycling infrastructure or cycle superhighways could lead to a strong uptake in active travel.
- Test Dutch-style interventions such as reallocating road space to buses and bikes, or creating low-traffic neighbourhoods[7].
- Produce heatmaps that reveal "low-hanging fruit" for intervention: OD pairs where car use is currently high but where active travel or public transport could become the lower-cost option with targeted investment.

In practical terms, this will allow us to say: "this particular flow between two neighbourhoods is currently dominated by cars, but could be most effectively shifted to cycling if dedicated lanes were added or this commuting route would likely see large mode shift if bus services were made more frequent or reliable".

7 Pucher, J. and Buehler, R. (2008), 'Making cycling irresistible: Lessons from the Netherlands, Denmark and Germany'. Transport Reviews, 28(4), pp. 495–528

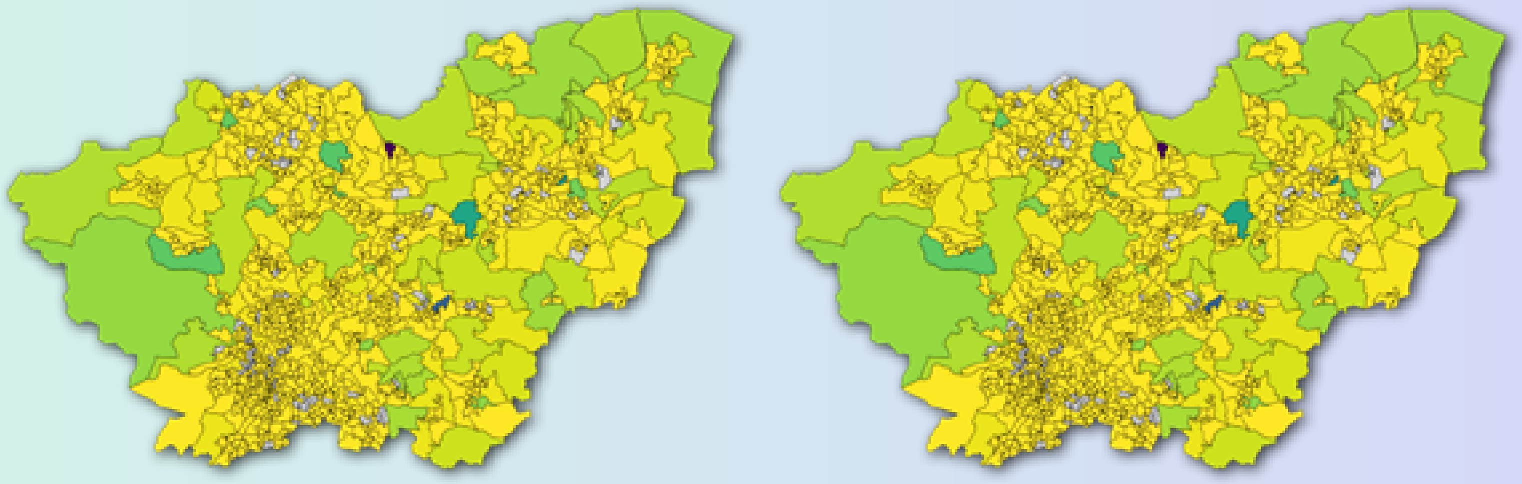


Figure 2 (a and b): ATT (a) and BU (b) after optimisation (UE)

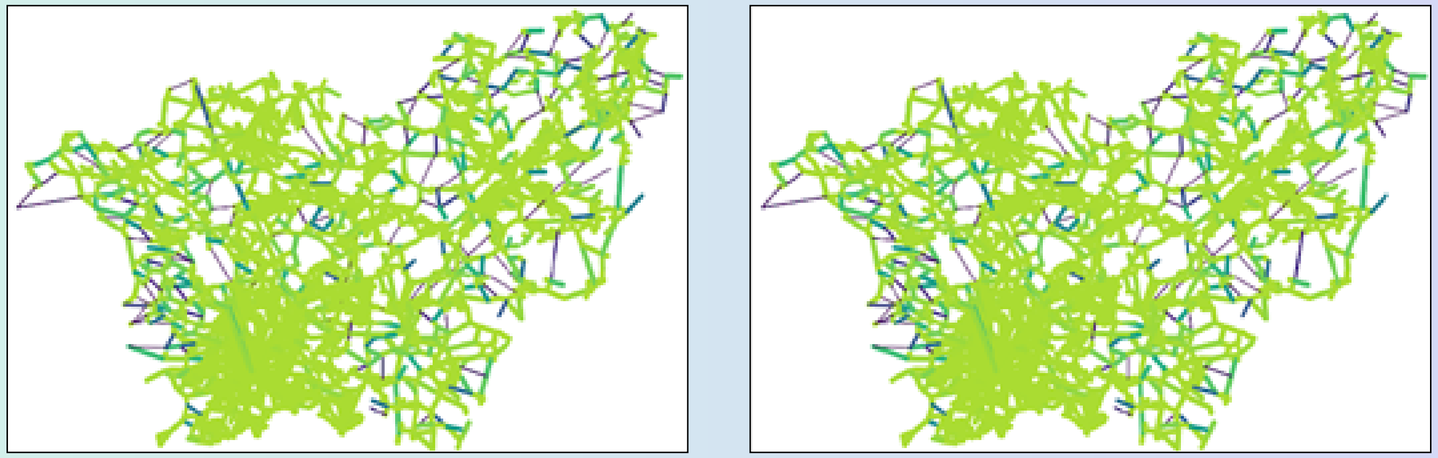


Figure 3 (a, b and c): AoN ATT (a), EU ATT (b), UE ATT - AoN ATT (c)

As a demonstration, we can start by identifying roads and routes where our prototype mode identifies promising expectation for people to choose alternatives to cars. Starting with existing data on car traffic flows between local areas, which tells us how many cars pass through each road, and then applying the relationships identified in our causal loop, such as how congestion impacts the choice to walk or cycle, we estimate the likelihood of a person choosing a car, a bus, or an active mode for any given journey. By isolating that "active" portion, we can pinpoint specific roads and routes where current conditions and traffic patterns already create a high probability for people to choose walking or cycling over driving. This shows us where the shift away from cars is already most likely to happen based on the real-world behavior of the traffic network.

What does this mean for the region?

For South Yorkshire, this project will provide a first-of-its-kind evidence base for designing transport interventions that are both technically optimal and socially acceptable. The model offers policy makers a tool to test interventions before committing resources, reducing uncertainty and improving decision-making.

The implications are wide-ranging. For example, by identifying routes most suitable for active travel, investment in cycle infrastructure can be targeted where it will have the greatest impact. Similarly, by simulating how bus service enhancements would shift demand, the region can prioritise investments that reduce congestion and emissions most effectively. These kinds of modal shift models have proven to be highly beneficial worldwide[8, 9, 10].

The benefits extend beyond efficiency. Shifting demand away from private cars will improve air quality, reduce GHG emissions, and promote healthier lifestyles through active travel. Crucially, by basing the model on stakeholder engagement, the project ensures that the recommended interventions align with local needs and values, making them more likely to succeed in practice.

Next Steps

The immediate next step is the workshop result refinement, consisting in optimising the formulations that translates preferences and propensities to quantifiable shifts across transport modes. After these activities, we will validate our model as an engine for understanding the potential effect of policies and structural interventions aimed at shifting the transport mode towards the most sustainable direction.

The modelling work will then produce a series of scenarios tailored to regional priorities, such as: (1) shifting commuting trips from cars to public transport through service frequency improvements; (2) designing active travel corridors between key employment centres and residential areas, and; (3) testing the impacts of low-traffic zones or car-free city centre policies.

These outputs will be shared with SYMCA and other stakeholders through visual tools such as heatmaps and dashboards. Over time, the model is positioned to be adapted for continuous use, supporting dynamic and responsive transport planning across South Yorkshire.

8 Shirzadi Babakan, A., Alimohammadi, A., and Taleai, M. (2018), 'An agent-based evaluation of impacts of transport developments on the modal shift in Tehran, Iran'. Case Studies on Transport Policy, 6(4), pp. 600–608.
9 Barbet, T., Nacer-Weill, A., Yang, C., and Raimbault, J. (2022), 'An agent-based model for modal shift in public transport'. Procedia Computer Science, 184, pp. 432–439.
10 Salazar-Serna, K., Cadavid, L., and Franco, C. J. (2024), 'Modeling urban transport choices: Incorporating sociocultural aspects'. Transportation Research Part F: Traffic Psychology and Behaviour, 99, pp. 234–248.

South Yorkshire's Public Transport Network and Distributive justice:

Which Communities Face Poor Job Opportunities?

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Challenge Statement

Accessible transportation is at the heart of equitable societies; residents having equal opportunity to travel when, where, and how they want, at affordable costs. Moreover, high quality, high connectivity transport networks support regional development and regional economic growth. Transport for the North (TfN) names "sub-optimal transport links and underinvestment in transport" as one of the key attributes of the 25% gulf in Gross Value Added (GVA) between the North and other areas of England. In 2014, this gap equated to a £4,800 per person difference in income between the North and the UK average, and a £22,500 per person difference between the North and London[1]. According to the Centre for Cities 2021 report titled 'Measuring up: Comparing public transport in the UK and Europe's biggest cities', the productivity gap, due to weak public transport accessibility in Sheffield, stood at £2.3 million[2].

The South Yorkshire Public Transport (PT) network consists of buses, trains, and trams (see Figure 1). Tram services run primarily in Sheffield, but also connect Sheffield to Rotherham via the tram-train. Well-routed and affordable public transport (PT) services, running at sufficient frequencies, are key to minimising community exclusion and connecting people to the jobs, services and leisure facilities available in their area.

Understanding regional transport accessibility can reveal missed opportunities – particularly in terms of employment and economic activity – resulting from mobility barriers[3]. However, there is currently no analysis of South Yorkshire's PT network that reveals the spatial distribution of job accessibility for each community.

Moreover, assessing job accessibility is more complex than the presence or absence of PT infrastructure; socio-economic factors affect PT affordability for some communities. Therefore, the spatial distribution of job accessibility must be measured by quantity and types of job opportunities from a given location that can be accessed and are affordable using existing PT services.

1 Transport for the North (2019) Northern Powerhouse: Independent Economic Review Core Messages
2 Centre for Cities (2021) Measuring up: Comparing public transport in the UK and Europe's biggest cities
3 Crisp, R., Gore, T., McCarthy, L., (2017), 'Addressing transport barriers to work in low income neighbourhoods: A review of evidence and practice'. Sheffield Hallam University.

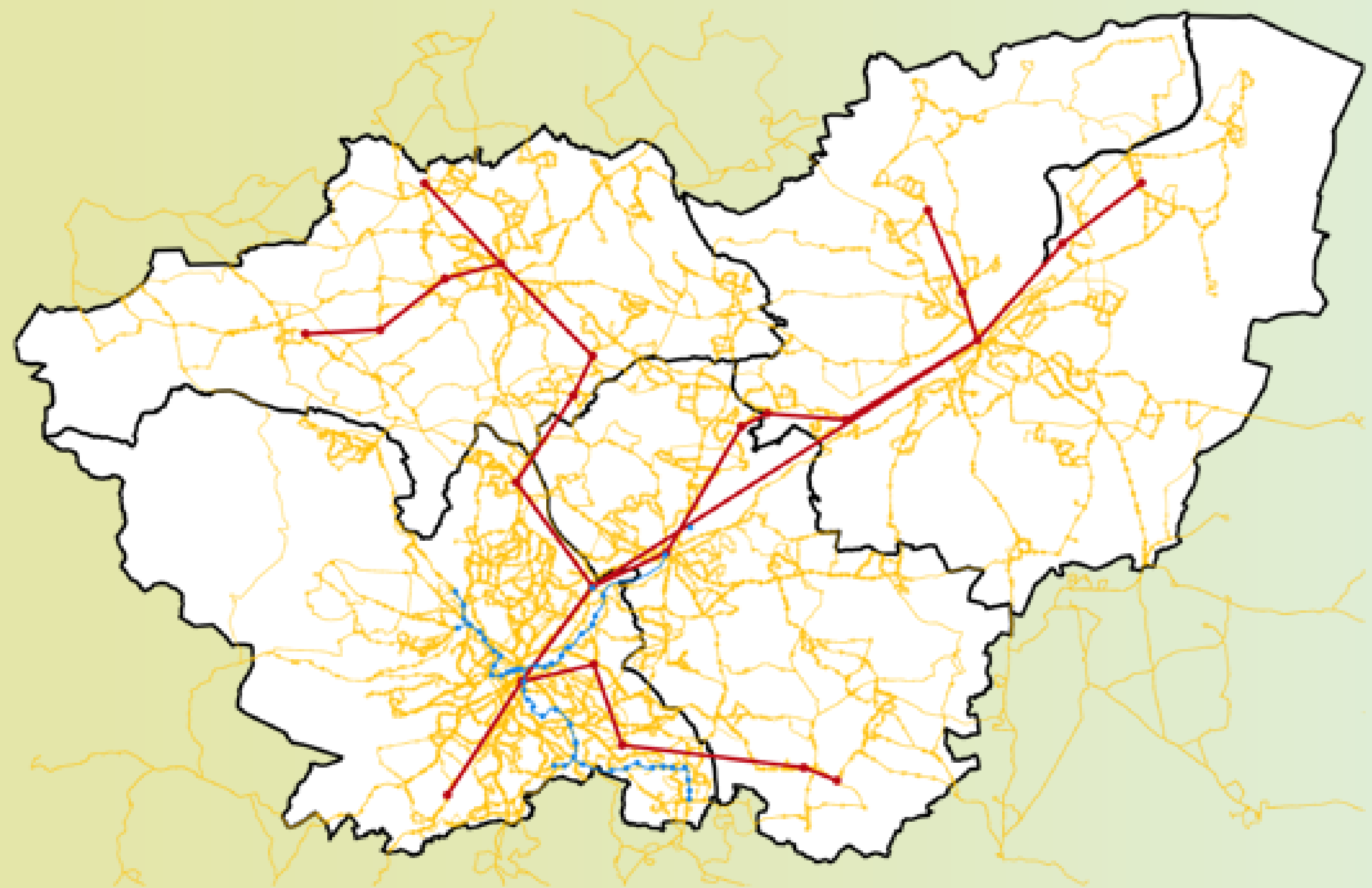

Figure 1: The public transport network of South Yorkshire, up to date as of May 2025. Mode key: yellow - bus, red - train, blue - tram.

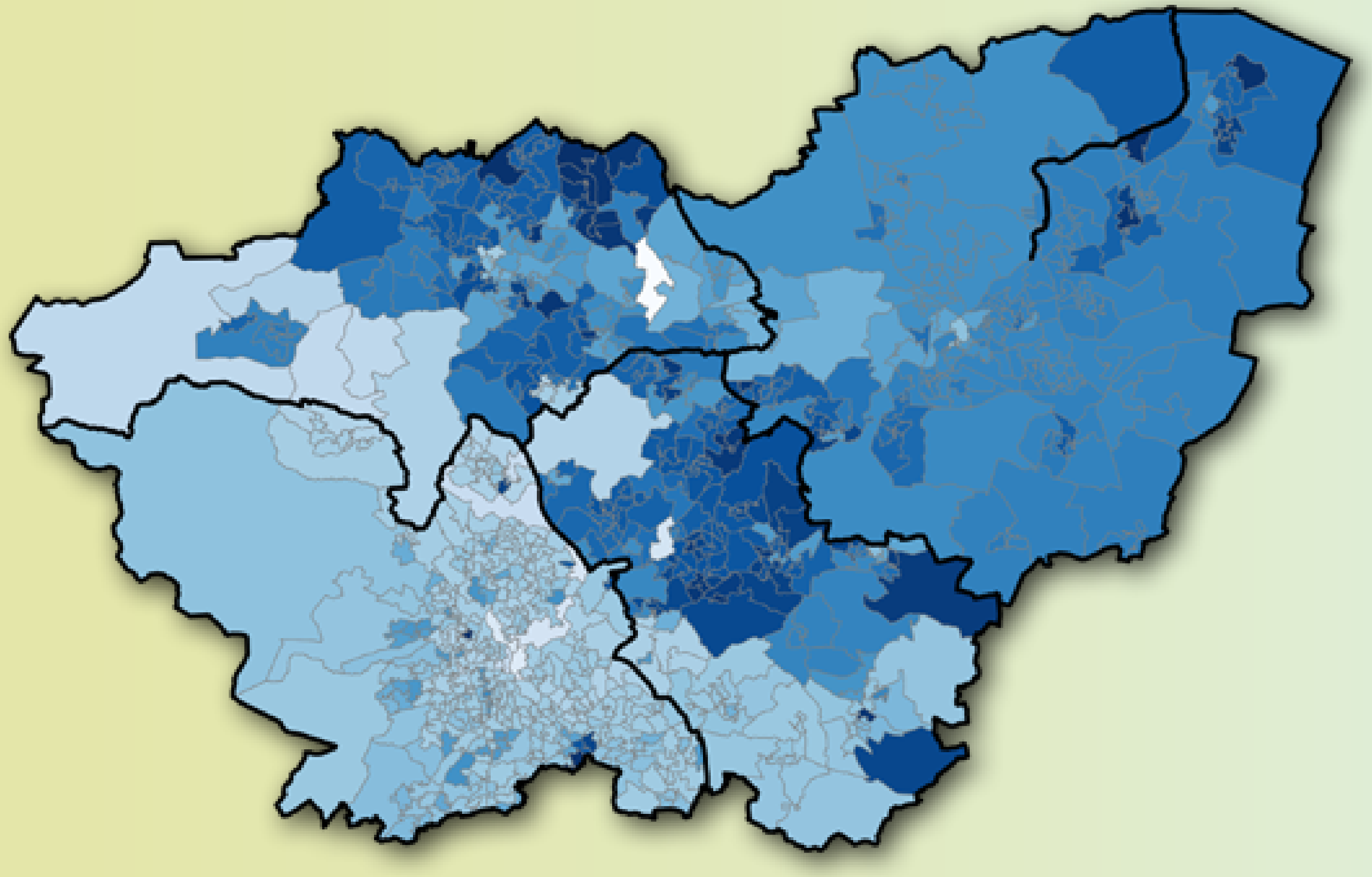

Figure 2: How many job opportunities are accessible from LSOA by public transport during peak commuting hours: weekdays 7-9am and 4-7pm. A maximum commuting threshold of 45 minutes is applied, with maximum 3 transfers.

Research Response

We assessed regional job accessibility using the current PT network of South Yorkshire, taking ‘communities’ as populations within lower-layer super-output areas (LSOAs). Spatial data for all current bus and tram services was provided by the South Yorkshire Mayoral Combined Authority (SYMCA), including service frequencies. Local train data was obtained from online service routes and timetables.

Different kinds of jobs require different in-person hours, and therefore, different commuting times. We provide our main analysis during peak commuting hours: weekdays from 7-9am and 4-7pm. To account for shift work, we also investigate PT options during typical hospital and warehouse commuting hours: all week from 5-7am, 3-5pm, and 9-11pm for hospitals, and all week from 4-6am, 12-2pm, and 8-10pm for warehouses. In doing this, we capture all key timebands where PT services run regionally across all three commuter scenarios.

We extracted three key metrics: (1) how many direct routes exist between all pairs of LSOAs; (2) modelled time spent travelling; and (3) minimum number of changes required. We assumed that transfers between all modes of PT can be taken within 800m, as this aligns with the maximum acceptable walking distance planning standard for train stops in the UK[4]. In alignment with SYMCA’s bus service improvement plan[5], we assumed that commuters accept a maximum of a 45 minute commute each way. For tractability and realism, we adopted a cap of three transfers in our model.

To understand PT ‘affordability’, we used the

4 WYG/Rapleys (2020) How far do people walk? (CD3.38 WYG). Rapleys.
5 SYMCA (2024) Bus Service Improvement Plan Refresh 2024. South Yorkshire Mayoral Combined Authority, Sheffield.

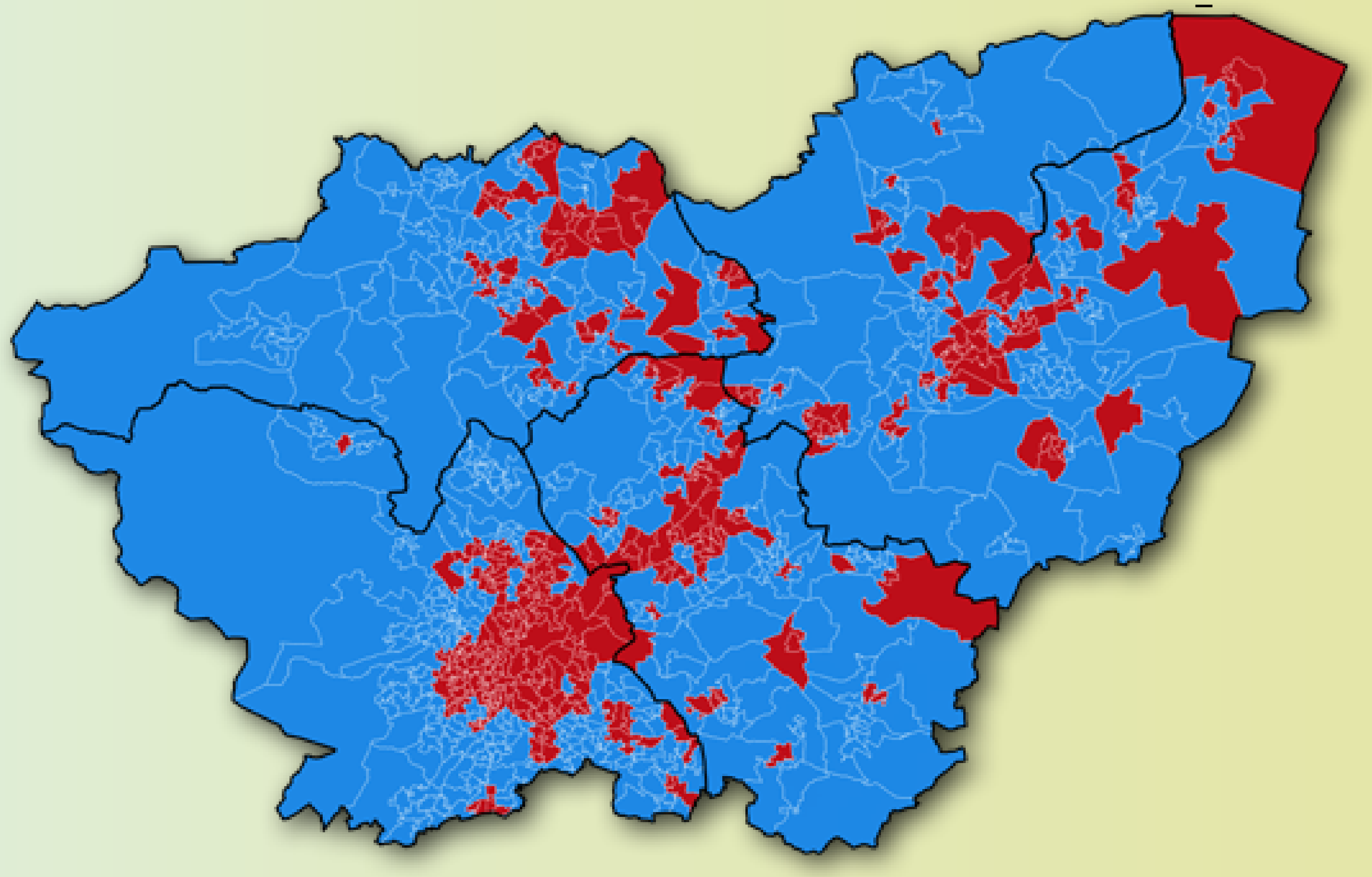

Figure 3: Transport affordability map of South Yorkshire, based on the outcome of a logistic regression model trained on a South Yorkshire survey, and applied to representative synthetic population data (Lomax et al., 2025).

household energy consumption survey undertaken by Jayne Carrick and Matthew Wood. This survey represents 623 respondents across South Yorkshire, who provided five key outputs for this study: (1) age; (2) working status; (3) income; (4) education level, and; (5) whether or not they are struggling to pay for their transport bills. The latter of these is a binary response, which we sought to characterise in terms of the first four respondent attributes.

By revealing how transport accessibility and affordability align with, or exclude, communities from economic opportunities, our framework empowers planners to design equitable transport systems that enable mobility.

Evidence and Outputs

Using our 45-minute limit for maximum acceptable travel time, we identify ‘reachable’ LSOAs during peak, hospital, and warehouse hours - see Figure 2 for results during peak hours. Comparing accessibility rankings to the number of registered companies in each LSOA, we find a visually intuitive overlap between areas of high economic activity and high accessibility.

Significant disparities emerge between those who rely on public transport and those with access to private vehicles. When these disparities are examined in the 24hrs cycle, it appears that existing transport strategies understandably focus on morning and evening peak travel times addressing high-demand routes. Yet this approach tends not to capture many lower-paid roles in sectors like healthcare and warehousing that require travel during “off-peak” hours. The analysis shows that public transport accessibility drops significantly during these shift-change windows, disadvantaging workers without cars in accessing these job opportunities.

Figure 3 shows the predicted transport

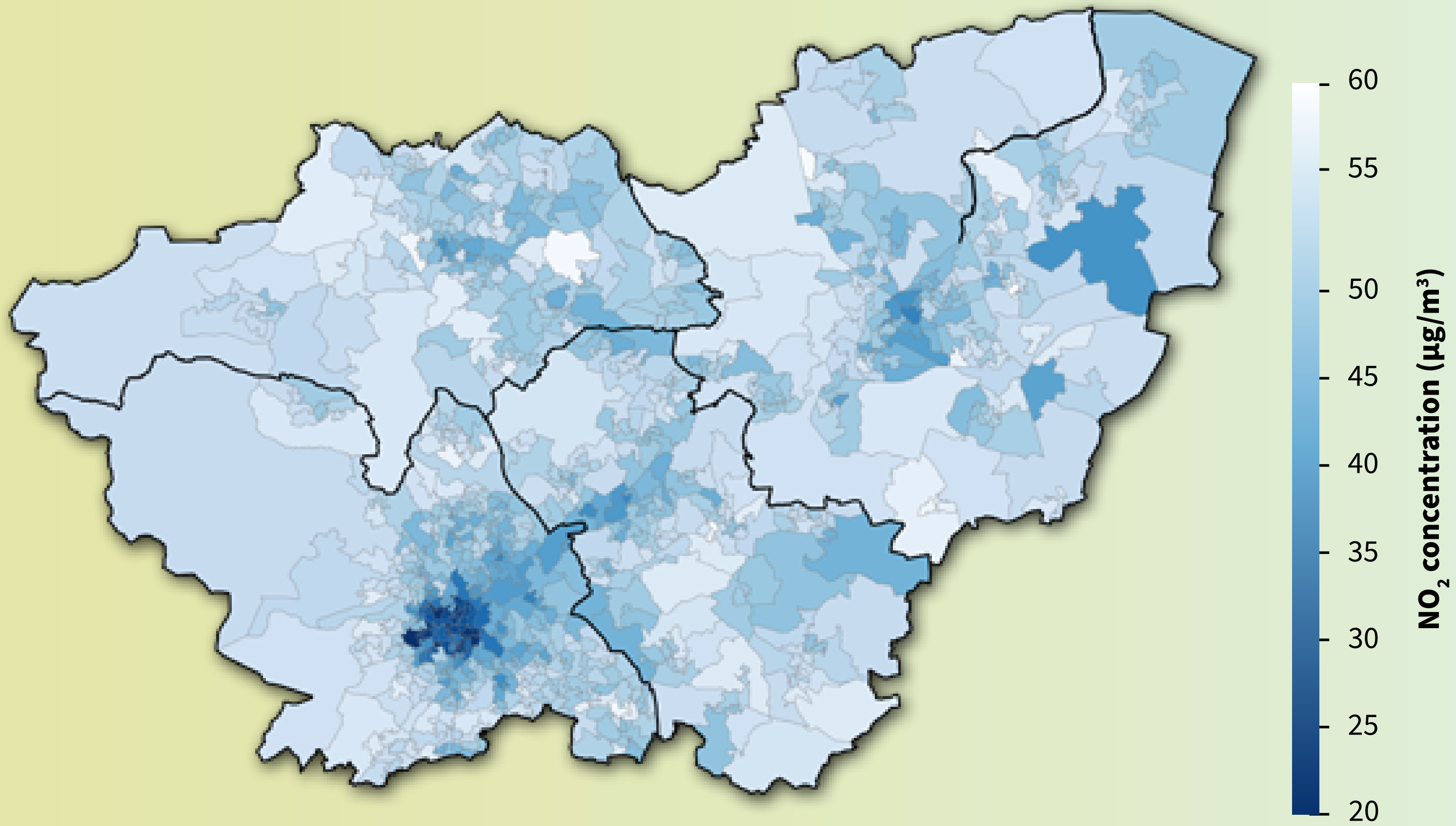

Figure 4: Map of the median age of residents within each LSOA, created from synthetic population data which matches actual census data when aggregated at LSOA level (Lomax et al., 2025).

affordability map for South Yorkshire at LSOA level. The number of LSOAs predicted to struggle paying for transport in each of the four local authorities are as follows:

- Barnsley: 47 (32% of total in region)
- Doncaster: 74 (38% of total in region)
- Rotherham: 59 (35% of total in region)
- Sheffield: 153 (44% of total in region)

This shows that Sheffield residents in particular may experience difficulties paying for transport. Doncaster is predicted to be the second most unaffordable region, followed by Rotherham, then Barnsley as the most affordable.

The key explanatory variable for this result is residents' age: the mean age for those struggling to pay was 21, while the mean for those not struggling was 54. Sheffield was found to be the most unaffordable because of the relatively large population of young people (university population) located within and around the city centre (see Figure 4), which is likely to explain the result.

However, when looking at personal report data, such as surveys, it's important to bear in mind that how each person interprets the response may differ. For example, an older person living rurally and who owns a private car may have a different perception of what 'struggling to pay for transport' looks like, in comparison to a young parent living near to the city centre who relies on PT. Understanding how much each respondent spends on transport per month could help to bridge this gap, especially in combination with household/personal income data.

What does this mean for the region?

To meet the goal of increasing the proportion of economically active people living within 30 minutes of employment, findings suggest that current strategies must be adjusted. In particular, attention should be shifted towards the less economically active areas where PT access points are fewer than in high workplace density areas.

PT stops are closely located to major attractors (e.g., workplaces) to promote accessibility. This generates a network that connects economically active areas, de facto excluding less affluent neighbourhoods in the region.

The transition to public control of buses by 2027 provides a mechanism to address these gaps. However, the research suggests that a demand-driven model, which prioritizes routes based on existing high usage, will not resolve the underlying inequalities. Attention should be shifted to link economically diverse areas to avoid islanding both geographically and temporally, across times of the day outside peak hours. The region could use an equity-based approach and also introduce a simplified distance-based fare structure to eliminate the financial penalty of transferring between services. Otherwise, the transport network will continue to limit regional economic growth by keeping a significant portion of the workforce without cars disconnected from the existing labor markets.

Our results align well with published deprivation statistics for South Yorkshire[6, 7], suggesting that communities with low socio-economic status and skills deprivation also experience the highest difficulties paying for transport.

6 Opportunity Sheffield (2023) Spatial mapping of South Yorkshire highlights areas of education, skills and training deprivation. Teacake Club / SYMCA blog, 13 Feb 2023.
7 South Yorkshire Fire & Rescue (2013) Community Profile. South Yorkshire Fire & Rescue, Sheffield.

Modelling the Impact of e-cargo Bikes for Last Mile Deliveries in South Yorkshire

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Project partners:
Russell's Bicycle Shed

Challenge Statement

Urban logistics in South Yorkshire are dominated by fossil fuel delivery vans, which contribute significantly to congestion, poor air quality, and greenhouse gas (GHG) emissions. Last-mile delivery decarbonisation in particular was identified as an urgent challenge for the region by the South Yorkshire Sustainability Centre (SYSC), in order to meet regional net-zero targets. While e-cargo bikes are often highlighted as a promising solution to these challenges in European cities[1], there is little quantitative evidence on their feasibility in the United Kingdom outside of London.

This evidence gap makes it difficult for regional policymakers and businesses to make informed decisions about whether and how e-cargo bikes could realistically replace vans for local deliveries. E-cargo bikes currently remain a 'niche technology[2]', despite numerous and often promising trials with a range of large companies[3,4,5], as well as increasing private use[6]. There is a wide range of potential barriers to e-cargo bike use, including perceptions of rider safety[7], difficulty handling e-cargo bikes[8], a lack of familiarity or comfort with them[9], and limitations such as speed, range and capacity. Many barriers can be easily placed into one of two categories: difficulties transitioning to a novel delivery method (such as the need for training), and technical barriers (such as range and capacity). Implementation experiences and challenges were researched in more depth in a parallel SYSC Social Science study, e-cargo Cycle Schemes: Lessons for Policy Design.

1 Gialos, A. and Zeimpekis, V. (2023) 'Dataset for the electric capacitated traveling salesman problem'. Data in Brief, 50:109464.
2 Sherriff, G., Blazejewski, L., and Davies, N. (2023), 'Why would you swap your nice warm van, where you can eat your butties and listen to the radio?' Mainstreaming a niche of cycle logistics in the United Kingdom. Energy Re-search & Social Science, 99:103062.
3 Sainsbury's (2018) 'Sainsbury's trials UK's first grocery delivery service by electric cargo bike'.
4 IKEA (2022) 'Solar-powered cargo bikes deliver lower climate footprint'.
5 DHL (2021) 'DHL supply chain trials e-cargo bike for home deliveries'.
6 CleanCities (2024) 'London sees dramatic increase in cargo bikes'.
7 Hess, A-K., and Schubert, I. (2019) 'Functional perceptions, barriers, and demographics concerning e-cargo bike sharing in Switzerland'. Transportation Research Part D: Transport and Environment, 71:153–168, 2019.
8 Bicycle Association (2024) 'Cargo bikes & cycle logistics'.
9 Sherriff, G., Blazejewski, L., and Davies, N. (2023), 'Why would you swap your nice warm van, where you can eat your butties and listen to the radio?' Mainstreaming a niche of cycle logistics in the United Kingdom. Energy Re-search & Social Science, 99:103062.

Research Response

We set out to evaluate the technical feasibility and potential impact of e-cargo bikes compared with conventional vans for last-mile deliveries. To do this, we built a computational model of South Yorkshire's road network using open-source mapping data, Companies House business records, and traffic information provided by Sheffield City Council.

We combined this modelling with insights from local operators, including Russell's Bicycle Shed, who shared details of their experiences running e-cargo bike delivery services in Sheffield. Their input helped us ensure that assumptions such as average cycling speed and stop times were realistic for local conditions.

We modelled the distribution of businesses across South Yorkshire and developed a routing algorithm that allowed us to sample delivery points for both an e-cargo bike and a van, and simulate how long it would take each transport mode to deliver goods from the delivery depot, and the associated CO2 emissions.

Our work focused on four questions: (1) which businesses could benefit most from adopting e-cargo bikes; (2) how many delivery hubs would be required for viable operations; (3) how costs compared with conventional van services, and; (4) what scale of emissions reduction could be achieved through widespread adoption.

Evidence and outputs

Our analysis showed that e-cargo bikes can outperform vans in delivery efficiency across areas of up to 27 km^2, particularly in dense urban environments where vans are slowed by congestion and the need to find parking. Vans required on average four minutes of dwell time at each stop, compared with only one minute for an

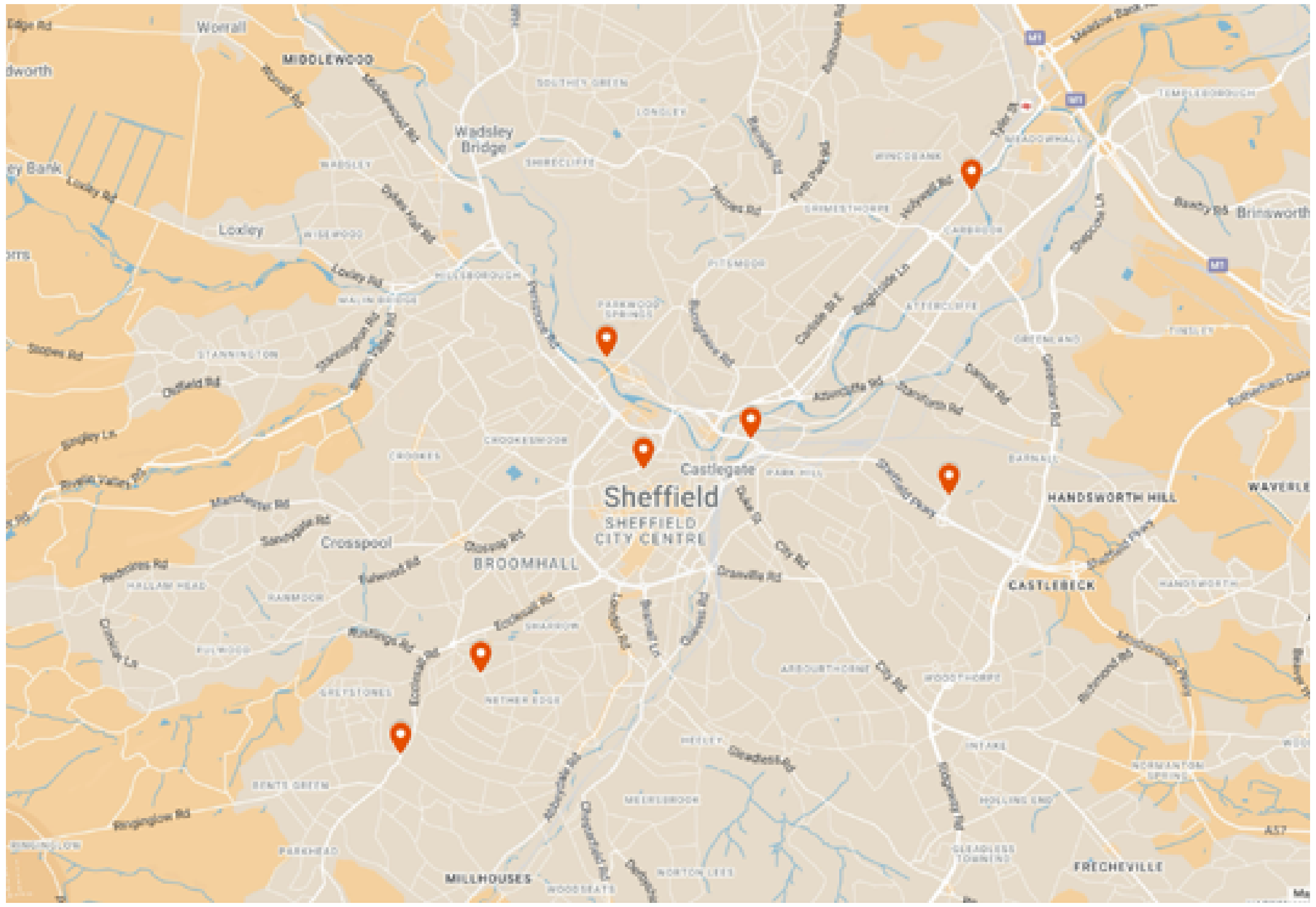

Figure 1: Map of the depots in Sheffield. Points are at the population weighted centroids of the seven LSOAs with largest numbers of businesses.

e-cargo bike. This gave e-cargo bikes a consistent advantage in high-density areas such as Sheffield city centre.

We found that at 31.5 km^2, both modes take an equal amount of time; we call this a 'critical point'. Below this critical point, e-cargo bikes are faster, whereas above this point, vans are faster. Figure 2 demonstrates how different size areas look across Sheffield, Doncaster, Barnsley and Rotherham.

In Sheffield the upper feasibility limit does not decrease below 16.6 km^2. This suggests that when delivery destinations are spread across areas smaller than this, e-cargo bikes take less time to complete routes than vans, regardless of the number of stops. A route of 30 stops takes approximately 4 hours to complete in Sheffield,

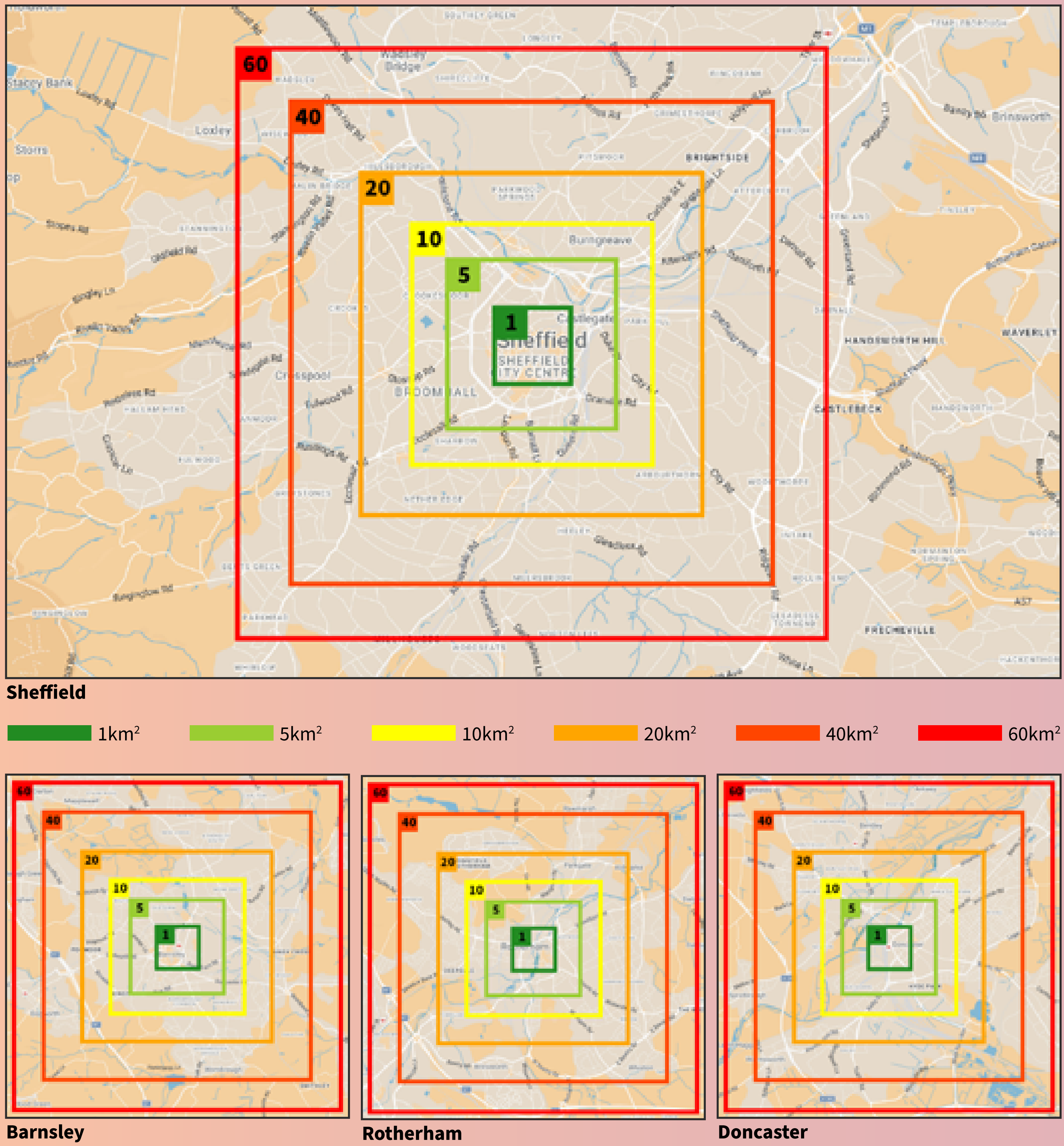

Figure 2: Maps to demonstrate how different size areas look across Sheffield, Doncaster, Barnsley and Rotherham. E-cargo bikes were found feasible: in Sheffield - areas ≤ 16km^2; in Rotherham and Barnsley - areas ≤ 50km^2; in Doncaster - with ≤ 25 stops across 25km^2

while the time to complete feasible routes of 10 or fewer stops typically does not exceed 2 hours.

In Doncaster, feasibility for e-cargo bikes is high for up to 12 stops, but then decreases sharply, with vans always taking less time than e-cargo bikes to complete routes of more than 26 stops. The rapidly increasing lower limit shows insufficient business density to allow many stops in the area.

Feasibility is exceptionally high in Rotherham and Barnsley, with both local authorities having upper limits that do not substantially decrease with increasing numbers of stops. On routes of 40 stops spread across 80 km^2, e-cargo bikes take less time than vans despite making a mean of 5.9 and 6.2 subtours (between which more packages are picked up from the depot) in Rotherham and Barnsley, respectively.

In terms of environmental impact, switching from vans to e-cargo bikes reduced emissions by an average of 10.8 kilograms of CO_2 equivalent per delivery route, with potential savings of up to 20.1 kilograms depending on route length and density. At scale, replacing one diesel van with an e-cargo bike performing three routes per working day would save around 8.2 tonnes of CO_2 equivalent per year.

What does this mean for the region?

We found that small and medium-sized enterprises, particularly those located in central urban areas, stand to benefit most from adopting e-cargo bikes. Goods such as groceries, coffee, documents, and medical supplies are especially well suited to this delivery mode. Larger businesses may still find value in partial adoption, with e-cargo bikes complementing vans for some types of deliveries.

Our modelling also showed that cities the size of Sheffield would require around five strategically placed hubs, ideally located on arterial routes or near consolidation centres. This finding aligns with emerging models of urban consolidation hubs in other regions, where goods are transferred from large vehicles to smaller, cleaner modes for the final stage of delivery[10].

Our findings provide strong evidence that e-cargo bikes can play an important role in decarbonising logistics in South Yorkshire. For policymakers, the key message is that e-cargo bikes are not only viable but can in many cases be more time-efficient than vans. They also offer direct air quality and climate benefits through reduced emissions.

The transition will require supportive policies to overcome barriers such as perceptions of limited capacity and low demand. Financial incentives, such as grants or credits linked to clean air zone compliance, could help reduce the cost barrier for businesses. Investment in cycle infrastructure and the establishment of urban logistics hubs would further enhance feasibility and adoption.

Although we found strong potential in Sheffield and Rotherham, where business density is high, feasibility was lower in Doncaster due to faster arterial roads that favour vans. This suggests that regional adoption strategies may need to be tailored to local transport networks

Next Steps

The next stage for South Yorkshire could be to pilot e-cargo bike delivery schemes with local businesses, particularly small enterprises in dense urban centres.

Demonstration projects could help build confidence among businesses that remain sceptical of the service's capacity and reliability. Rich qualitative information was developed through a parallel SYSC study, e-cargo Cycle Schemes: Lessons for Policy Design.

There is also an opportunity to integrate e-cargo bikes into wider transport and decarbonisation strategies, including the development of urban consolidation centres. Additional research should focus on identifying thresholds of business density that determine viability, and on assessing how dedicated cycle infrastructure might further improve delivery efficiency.

10 Dreischerf, A. J. and Buijs, P. (2022) How urban consolidation centres affect distribution networks: An empirical investigation from the perspective of suppliers. Case Studies on Transport Policy, 10(1), 518–528.

E-cargo Cycle Schemes: Lessons for Policy Design

Project team:
Sheffield Hallam University: Mia Rafalowicz-Campbell, Centre for Regional Economic and Social Research

Challenge Statement

In South Yorkshire, urban logistics is dominated by fossil fueled delivery vans, which contribute significantly to congestion, poor air quality, and greenhouse gas (GHG) emissions. E-cargo cycles hold the potential to reduce emissions, improve inner city air quality, create 'green' jobs, and allow businesses to avoid the Clean Air Zone restrictions in Sheffield city centre. A report by climate charity Possible showed that e-cargo cycle deliveries in London are on average 1.61 times faster than vans, as well as saving significant CO2 and NOx emissions. Moreover, the annual running costs of e-cargo cycles were cited as £5,700 lower than for small diesel vans (£300 versus £6,000) based on research conducted by the Energy Saving Trust.

While e-cargo cycles are often highlighted as a promising solution in European cities, there is little quantitative evidence on their feasibility in the United Kingdom outside of London. This evidence gap makes it difficult for regional policymakers and businesses to make informed decisions about whether and how e-cargo cycles could realistically replace vans for local deliveries.

Significant challenges remain for this sector that has precluded them from entering the mainstream, remaining in the UK a "niche technology". There are also many barriers to e-cargo cycle use such as perceptions of rider safety, difficulty handling e-cargo cycles, a lack of familiarity or comfort with them, and limitations such as speed, range and capacity.

Research Response

The research addresses the following objectives: to synthesise what is already known about successful e-cargo cycle scheme implementation in terms of policy design and business perceptions, and to synthesise learning for implementation of future e-cargo cycle scheme development.

This complements a parallel study conducted through SYSC, Modelling the impact of e-cargo bikes for last mile deliveries in South Yorkshire, which investigates the technical feasibility (in terms of delivery time and delivery capacity) of e-cargo bikes in South Yorkshire as a means of replacing last mile or short distance deliveries currently conducted by fossil fueled HGV / LGV vehicles.

This project conducted a review of literature on e-cargo cycles as well as interviews with the representatives listed in Table 1.

Informal discussions were also held with representatives from City of York Council, London Borough of Hackney, Norfolk County Council, the latter's academic partner, as well as a Sheffield cycle shop with cargo cycle hire.

Evidence and Outputs

Successes

Overall, the try-before-you-buy schemes were considered the most successful - *"over half of the people who try one out actually go on to purchase one themselves"* (CaCC-PATO) - as it gave people the confidence to invest significant sums in the equipment, training and business process changes required.

In Colchester, an individual who obtained one of the Council's original fleet went on to launch Colchester e-cargo, which now employs 12 people covering pickups, deliveries, a city centre to home delivery service, and a contract with the e-scooter and ebike rental/sharing service to maintain and manage its Colchester fleet.

There were also strong use cases for Small and Medium Sized Enterprises. For example, a nursery in Brighton that used to send a member of staff in

Organisation	E-cargo bike fund	Interviewee role	Attribution acronym
Manchester City Council	£173,638.3 funded in 2021/22	Principal Resources and Programmes Officer	MCC-PRPO
Sheffield City Council	£158,360 funded in 2019/20	Senior Transport Planner	SCC-STP
Cambridgeshire County Council	£168,679 funded in 2019/20	Principal Active Travel Officer	CaCC-PATO
Colchester City Council	£135,988 funded in 2019/20	Transport and Sustainability Joint Lead	CoCC-TSJL
Zedify	n/a – delivery service partner	Brighton Hub Manager	Z-BHM

Table 1: Project interviewees

a taxi to deliver nursery meals was able to use an e-cargo bike to deliver the food to all stops in one hour.

Zedify was also contracted to visit SME clients with small rubbish loads, which they then delivered to a central collection point for a larger truck to collect. Businesses positioning themselves as sustainable found it was appreciated by customers too.

e-cargo cycles had also been used to replace some journeys by Council teams; cycles for internal use have largely been directed to the parks teams and others working outdoors, as *"those are the kind of people who are not fazed by having some outdoor clothes on and getting on a bike"* (MCC-PRPO). However, Sheffield City Council also found that *"it's quite difficult to get them [the cycles] out. It's still quite early days in terms of people feeling confident to use them"* (SCC-STP).

Challenges

The research identified a number of key challenges:

- business **resistance to change** in adoption of a new technology
- **safety and security** of both riders and the cycles
- **precarious working practices** in the cycle delivery sector
- generating sufficient **public awareness** and support
- **lack of local authority resources** in supporting this transition.

Resistance to change among businesses and the wider public was the number one challenge described by the interviewees. This resistance was encountered in the form of:

- **scepticism** or doubt around reducing costs
- **complications and confusion** around redefining operating models
- broader **uneasiness** relating to a new technology or change in general.

Furthermore, the research highlighted a cluster of concerns around the safety and security of both riders and cycles: the safety of the cycling environment and infrastructure in general, the ease of riding and control of e-cargo cycles, the storage and parking of the cycles and difficulties experienced obtaining adequate insurance.

The research produced rich qualitative findings, which can be found in the full report.

What does this mean for the region?

Recommendations about the shape of future trial schemes are as follows:

- Establish a try-before-you-buy fleet: there are a large variety of e-cargo cycles on offer, and end users often need help determining what will meet their needs.

- Streamline where possible and avoid running multiple different schemes at the same time.
- Ensure sufficient resources are allocated to management of schemes and maintenance of the fleet.

Collaboration between public and private sectors have also been key to the successful implementation of e-cargo delivery and logistics business models. To build successful partnerships we recommend:

- Seeking out those partners (or local champions) who are already helping to grow the presence of e-cargo cycles on the streets.
- Establishing a cross-sectoral alliance for information-sharing, mutual support, and lobbying power.

To overcome the varied challenges the research findings recommend:

- Working with successful e-cargo cycle operators, where available, in order to deliver sustained engagement and conversation with businesses, as well as an offer of support with redesigning operating models and practices.
- A renewed and continued commitment to investment in cycling infrastructure – to include e-cargo cycle parking and storage as well as sufficiently wide, segregated lanes.
- Targeting revenue funding to ensure sufficient resources for the maintenance, operation, and promotion of e-cargo cycle schemes.
- Incorporating public awareness campaigns into every stage of e-cargo bike programmes. At the same time, be prepared for some backlash.

Given local authority e-cargo cycle schemes have been dependent on external grant funding and are currently not sustainable into the long-term, the key question remains how to ensure future initiatives are able to survive beyond grant timescales to truly deliver a shift towards decarbonised transportation.

Next Steps

The second part of this research, "Modelling the impact of e-cargo bikes for last mile deliveries in South Yorkshire" has demonstrated quantitatively that there is a strong use case for e-cargo bike deliveries in some parts of the region. However, this research has shown that implementation is, in practice, challenging.

Based on the combined research conducted, we recommend that the region should build partnerships between interested parties in local government organisations, businesses, community groups and universities that can co-produce e-cargo bike projects and demonstrators using the results of viability modelling as a starting point.