Report on Intra- and Inter-Generated Traffic in South Yorkshire

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1 Introduction

The South Yorkshire Sustainability Centre (SYSC) is an organisation connecting world-leading research with regional partners, with the aim of developing and implementing plans to reduce emissions while also providing jobs and economic growth. The SYSC partnership is co-produced by the University of Sheffield, the South Yorkshire Mayoral Combined Authority (MCA), the four South Yorkshire local authorities (LAs), Sheffield Hallam University, and a range of private and voluntary sector organisations. Using the UN's Sustainable Development Goals, the centre will help organisations to consider not only the environmental aspects of sustainability challenges, but also balance these against economic and social factors in finding solutions.

Project 1.2 within the SYSC seeks to provide data-driven solutions to reduce transport emissions across South Yorkshire. In particular, the project aims to develop a unified platform for urban mobility, enabled by a data-driven and complexity based approach to include private mobility, public transport, and scenario analysis for the spread of active travel. The model will be co-created with partners at the MCA transport group and include economic aspects (e.g. the need to connect production and residential areas) as well as environmental sustainability of the transport network. This will address questions such as where interventions and investments should be placed to favour multimodal and active travel.

The objective of this report is to provide quantitative insight into how much traffic passing through each of the four South Yorkshire LAs is generated inside and outside of the region. This analysis is also extended to the South Yorkshire region as a whole.

2 Data

Data used was collected by The Floow [1] via car-mounted devices. These sensors are black boxes mounted on a small proportion of private cars, so total figures are obtained by expanding the data available to the volume of the circulating fleet of vehicles. When acquired, the data was in this expanded format.

Origin-destination (OD) data describing estimated daily traffic counts for journeys made on weekdays in 2019 was used. The data refers to all vehicles that have transited through South Yorkshire in 2019, regardless of their origin and destination, which could be within or outside South Yorkshire. Each row of the OD matrix corresponds to a journey's origin, and columns to destinations. Thus, the matrix

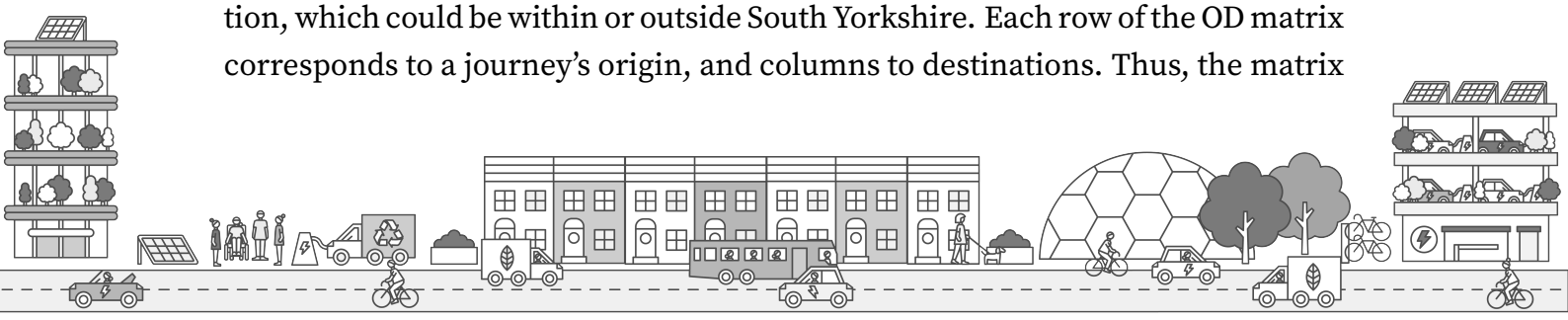


Table 1: Table showing the number of OD regions inside/outside each of the four South Yorkshire LAs, and South Yorkshire as a whole, for the OD matrix containing estimated daily traffic counts on weekdays in 2019.

Area	OD region count inside	OD region count outside
South Yorkshire	184 (90.2%)	20 (9.8%)
Barnsley	35 (17.2%)	169 (82.8%)
Doncaster	43 (21.1%)	161 (78.9%)
Rotherham	34 (16.7%)	170 (83.3%)
Sheffield	72 (35.3%)	132 (64.7%)

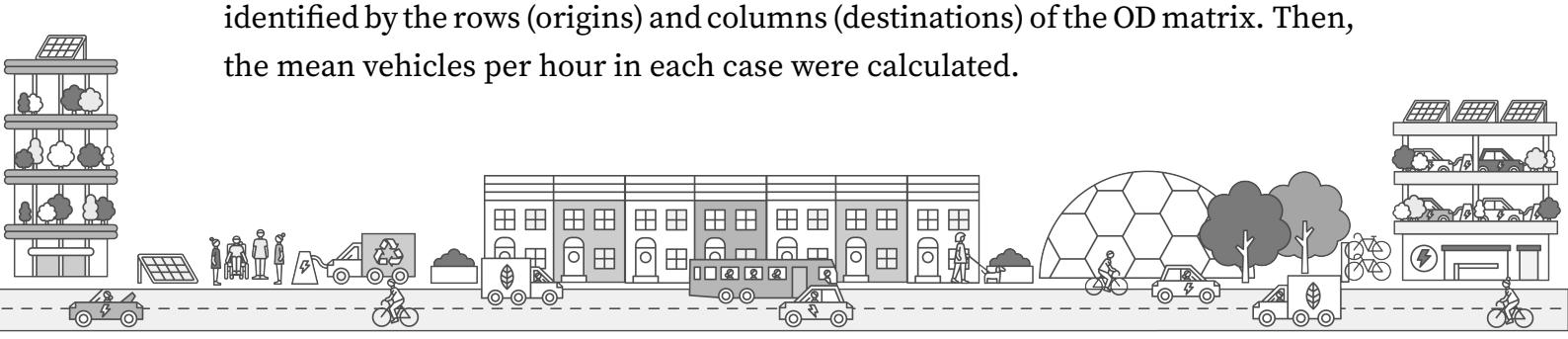
provides 204 ODs. Notably, only private motor vehicles are recorded in the traffic counts. Moreover, only commuting journeys are included, and these are considered as the journeys that connect origin to destination and return to origin within the same day. The data therefore accounts for a daily traffic volume of 315,624 vehicles per hour. ODs are given at middle layer super output area (MSOA) level within South Yorkshire, with decreasing level of granularity as distance from this region increases. Of the 204 ODs, Table 1 shows how many of these are within each of the LAs, and South Yorkshire as a whole.

3 Methods

Five regions were considered, one for each local authority, and one for South Yorkshire as a whole. For each region, the journeys were grouped in 4 categories depending on their origins and destination being within or outside the region. Four cases are then possible:

1. Outside/outside: journeys both start and end outside the region (Local Authority or South Yorkshire),
2. Inside/inside: journeys both start and end inside the region,
3. Inside/outside: journeys start inside the region but end outside,
4. Outside/inside: journeys start outside the region but end inside.

For South Yorkshire as a whole, journeys in each of the above four cases were identified by the rows (origins) and columns (destinations) of the OD matrix. Then, the mean vehicles per hour in each case were calculated.



For the individual LAs, it was necessary to model journey routing. As an example, a journey starting in Leeds and ending in Sheffield may also pass through Barnsley, Doncaster, or Rotherham. For each OD region outside of South Yorkshire, the region was split into its constituent LAs. Then, the population weighted centroid of these LAs were computed according to the algorithm proposed by Kulin & Kuenne (1962) [5]. These centroids were used as origin and destination nodes. Notably, this method implies that multiple OD node pairs may be created between the same two OD regions (from the demand matrix), depending on the number of LAs in each OD region.

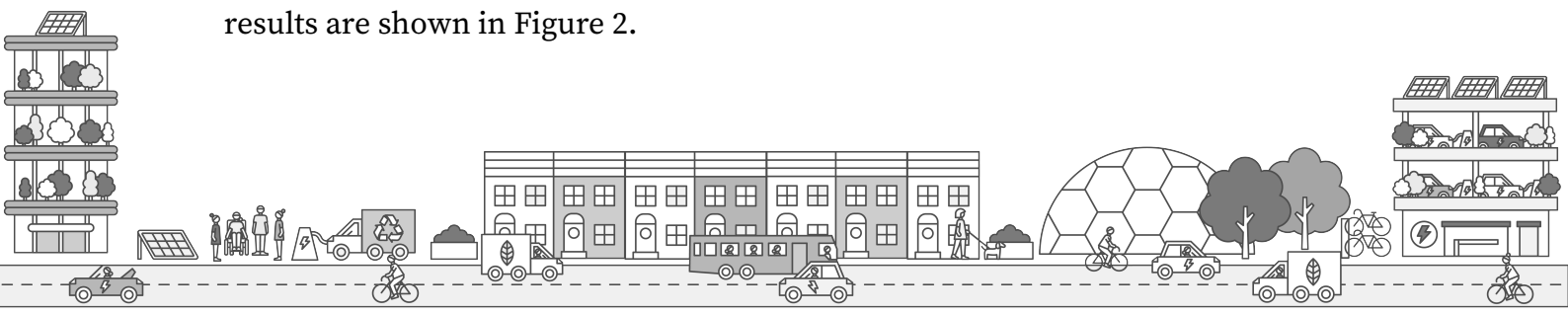
As road users generally favour routes that minimise their travel time [2], the shortest paths - based on the England major road network - were calculated between OD node pairs. For journeys both starting and ending outside of South Yorkshire, the shortest path connecting the OD nodes may not necessarily traverse the region. Yet these journeys, hence their associated OD demand, were not captured by the data. Outside/outside origin/destination data was mapped to journeys that were constrained to traverse South Yorkshire.

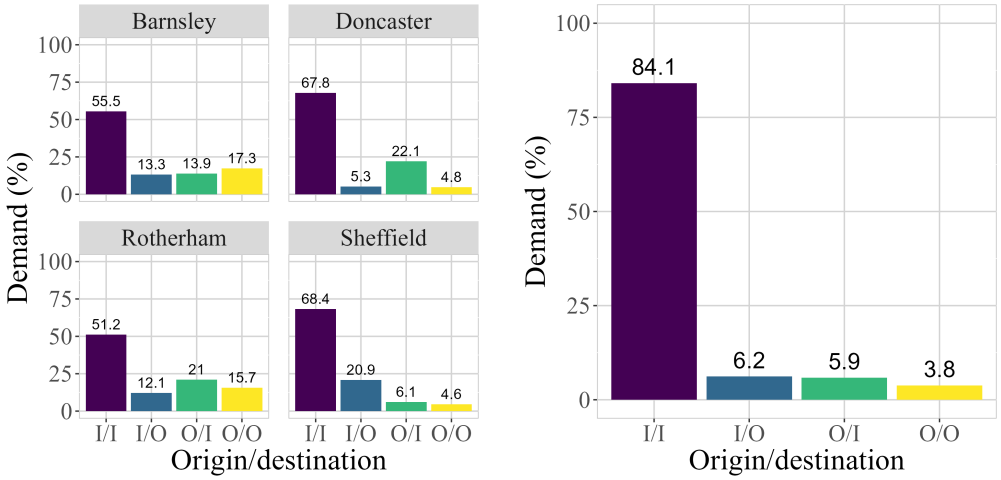
Demand was assigned such that if multiple routes exist for the same OD region pair, demand is split equally between these routes. The proportion of demand associated with the four OD cases was then able to be identified for each LA in South Yorkshire.

4 Results

The percentages of journeys that have origins/destinations inside/outside each of the four South Yorkshire LAs are displayed as bar charts in Figure 1a. It is seen that the majority of traffic within Sheffield is generated by journeys that start and end outside the region. For each of the other three LAs, the majority of traffic is generated by journeys that start and end inside the region. The split of traffic percentages for the South Yorkshire region as a whole is shown in Figure 1b.

It was also of interest to plot the distribution of journey lengths with respect to which of the four OD cases the journey corresponds to. For this, four histograms were plotted corresponding to each OD case, where the data count is weighted by the travel demand associated with each particular journey. This means that if many cars are travelling between an OD pair, the corresponding journey will have higher weight than a journey of the same length but with low demand. These results are shown in Figure 2.





(a) Local authorities. **(b)** South Yorkshire.

Figure 1: Bar charts for local authorities within South Yorkshire, and the region as a whole, showing the percentages of traffic flow for journeys starting/ending inside/outside the region of interest.

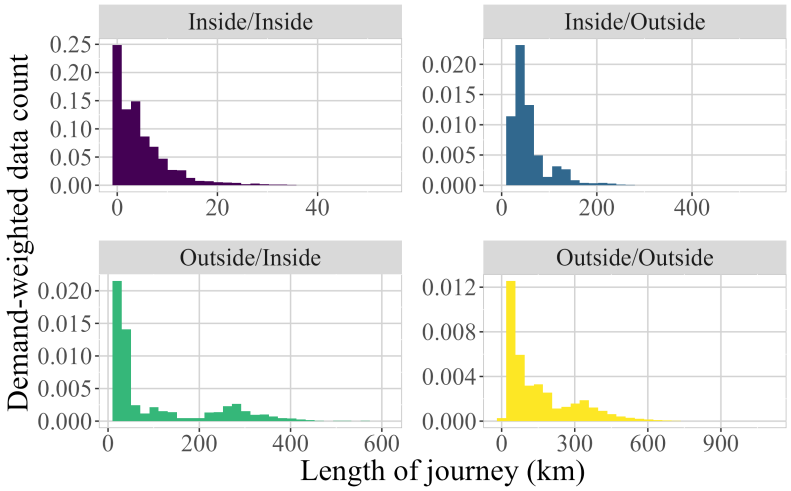
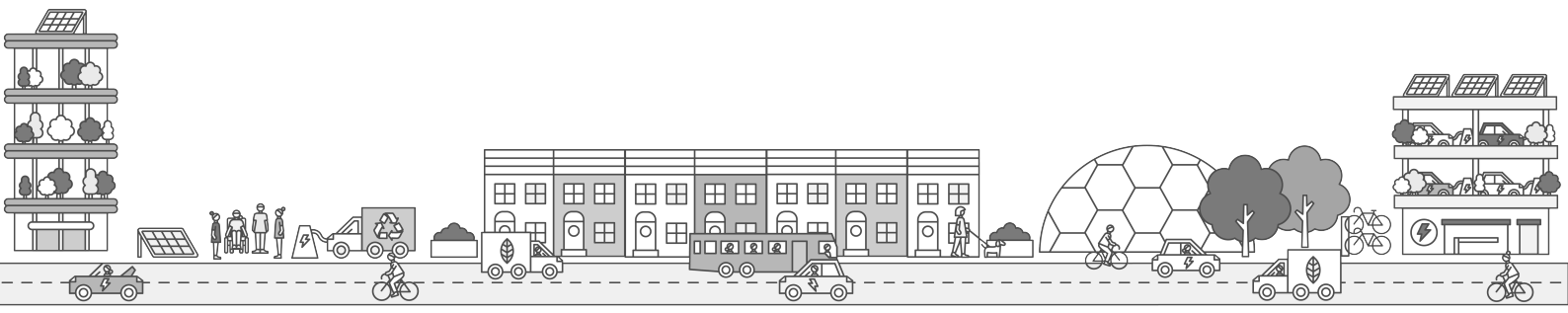


Figure 2: Histogram showing the distribution of distances for journeys starting/ending inside/outside South Yorkshire. Data counts are proportionally weighted by the demand associated with each journey.



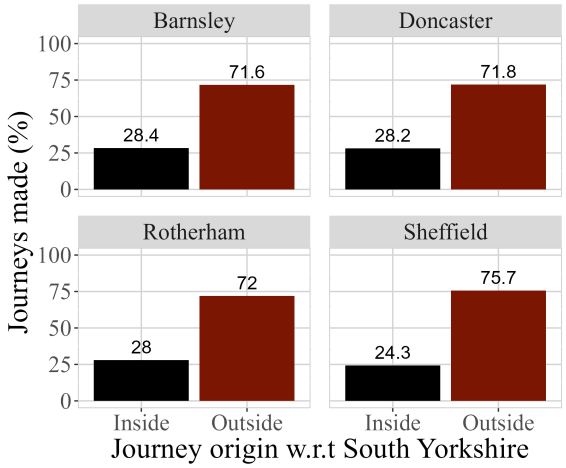
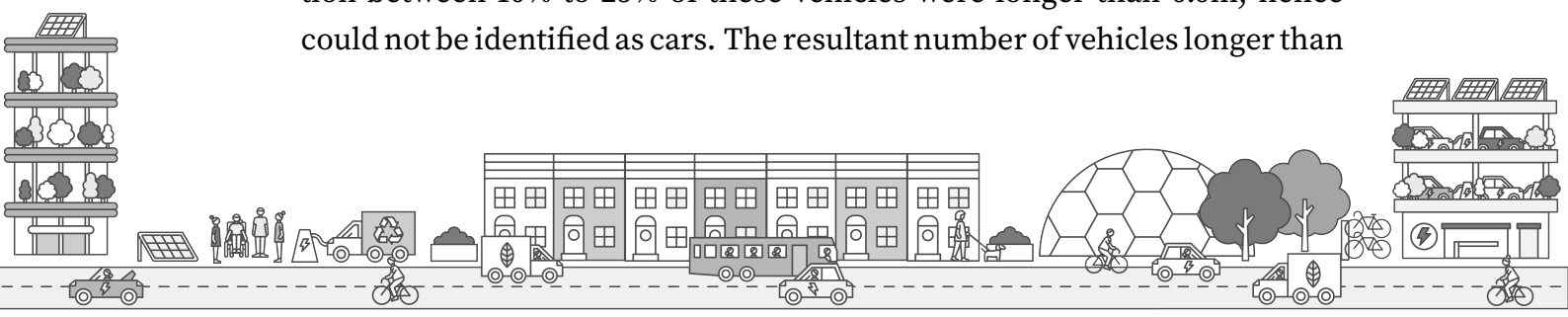


Figure 3: Bar chart limited to journeys both starting and ending outside each LA. The data is split according to whether these journeys originate inside or outside South Yorkshire (w.r.t: with respect to).

Lastly, for each of the LAs, only journeys that both start and end outside of the LA were considered. The aim was to quantify how much through-traffic for each LA originates within South Yorkshire, and how much originates outside of the region. To visualise this, a bar chart was plotted to for each of the LAs breaking down how many passing-through journeys are generated inside/outside South Yorkshire, respectively. This is given by Figure 3.

5 Conclusions

- From Figure 1b, the majority (84.1%) of all commuting traffic in South Yorkshire is seen to be generated by journeys that start and end internally. The least amount of traffic (3.8%) is generated by journeys passing through the region. This suggests that the majority of commuting traffic in South Yorkshire may be controlled by local interventions and behavioural changes of residents regarding transportation modes. As the figures refer to commuting traffic, most of long range traffic is not captured. Conversely, National Highway data [4] indicates that in the same period, the average daily traffic flow on the M1, measured at locations immediately outside South Yorkshire borders, has been between 45,000 and 63,000 vehicles per day, where the spread depends on which point of the motorway the data refers to. A fraction between 10% to 25% of these vehicles were longer than 6.6m, hence could not be identified as cars. The resultant number of vehicles longer than



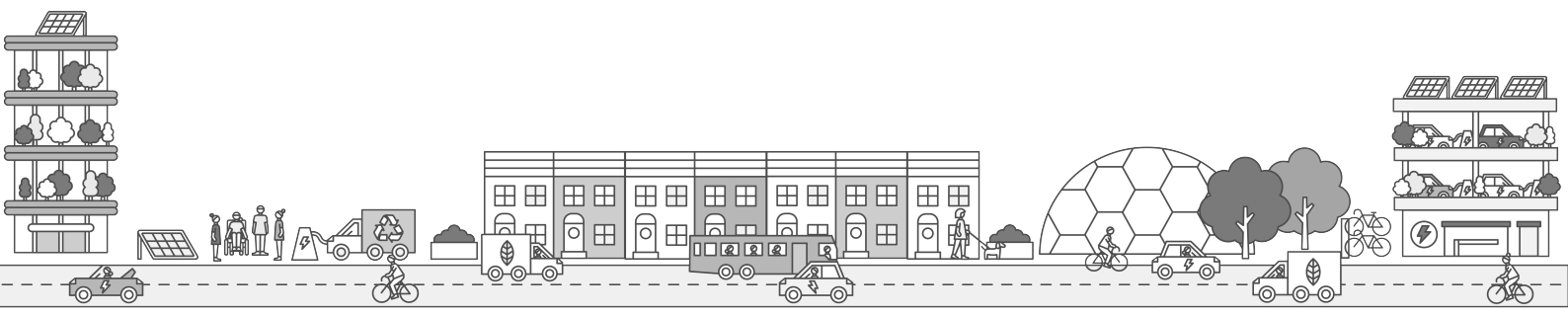
6.6m detected on weekdays was 9,655. The comparison with the daily traffic volumes we obtained from the origin destination data suggests that long range traffic passing through South Yorkshire via the motorway is small-scale with respect to South Yorkshire commuting traffic (26%).

- From Figure 1a, the majority of traffic within each of the four South Yorkshire LAs is generated internally (mean 60.7%), suggesting that most residents are likely to commute within the same LA they live in.

- Figure 2 confirms the national trend which sees 60% of car journeys to be within 5 mile (≈8km) distance [3]. This provides confidence in relation to this report's findings.

- The majority of the traffic passing through each local authority (i.e. with both origin and destination outside the Local Authority) is originated outside South Yorkshire (Figure3). In this case, there is little difference between the four local authorities with passing traffic generated inside South Yorkshire being bound between 24.3 and 28.4.

- Rotherham and Barnsley have the highest percentages of passing through traffic - i.e. out/out journeys - with 15.7% and 17.3%, respectively. As only private cars are included within this data, it may be that the total traffic demand (including heavy goods vehicles) changes the proportions of the results. In particular, as lorries are most likely to be travelling on motorways, it may be that traffic in Rotherham - which contains the M1 motorway - has a higher percentage of total out/out traffic than is shown in Figure 1a. This is however hardly influenced by local and regional transport and sustainability policies.



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[2] Comsis Corporation. *Traffic Assignment, August 1973: Methods, Applications, Products*. U.S. Department of Transportation, Federal Highway Administration, 1973.

[3] Department for Transport. National travel survey, data table nts0308, 2019.

[4] National Highways. Webtris, 2024.

[5] H. W. Kulin and R. E. Kuenne. An efficient algorithm for the numerical solution of the generalized weber problem in spatial economics. *Journal of Regional Science*, 4(2):21–33, 1962.