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## Research Article

**Keywords:** Scope 3 emissions, Greenhouse Gas (GHG) Protocol, Hybrid working patterns, Distance-Based Method, Average Data Method, Carbon accounting, Employee commuting

**Posted Date:** July 20th, 2026

**DOI:** <https://doi.org/10.21203/rs.3.rs-10059637/v1>

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**Additional Declarations:** No competing interests reported.

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# Comparative Carbon Accounting Using Distance-Based and Average Data Methods in Employee Commuting Emissions

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## Abstract

*Accurately quantifying employee commuting emissions remains a major challenge for local authorities due to inconsistencies in data quality and methodological approaches. Many organizations rely on simplified or national-average estimates that fail to capture local commuting behaviours, hybrid work patterns, and vehicle types, leading to significant uncertainty in Scope 3, Category 7 greenhouse gas (GHG) emissions reporting. This study compares two established methods for calculating commuting emissions—the Distance-Based Method and the Average Data Method—using Middlesbrough Council (UK) as a case study. A structured survey of 100 employees collected data on commuting distances, modes of travel, working arrangements, and fuel types. Emissions were calculated under both methods using the UK Government's (DEFRA) 2024 conversion factors. Results show that 66% of employees work in hybrid arrangements and 78% commute alone by car, making private vehicle use the dominant source of emissions. The Distance-Based Method estimated 1,241.07 tCO<sub>2</sub>e per year, compared to 811.47 tCO<sub>2</sub>e from the Average Data Method, revealing a discrepancy of approximately 429.6 tCO<sub>2</sub>e (34%). This difference reflects the Distance-Based Method's superior granularity, accounting for variables such as fuel type, commuting frequency, and remote-working patterns. Although more data-intensive, the Distance-Based Method provides a more accurate representation of employee commuting emissions and is recommended for councils seeking robust and transparent Scope 3 reporting. This study—the first to empirically compare both methods in a UK local government context—offers a scalable framework to enhance carbon accounting precision and inform sustainable transport and climate policy globally.*

**Key Words:** *Scope 3 emissions, Greenhouse Gas (GHG) Protocol, Hybrid working patterns, Distance-Based Method, Average Data Method, Carbon accounting, Employee commuting*

## 1.0 INTRODUCTION

The UK's commitment to achieving net-zero emissions by 2050 has driven action across business, education, government, and non-governmental sectors (Okonta & Rahimian, 2024; Molthan-Hill et al., 2020). Despite this progress—including a 44% reduction in emissions from 1990 levels by 2021—significant challenges remain, particularly in greenhouse gas accounting, where issues like organizational boundary selection can distort reported figures (Smith, 2016). Further obstacles include the transition from fossil fuels to renewables, economic trade-offs,

and the need for widespread behavioural change (Shahzad et al., 2024). Overcoming these challenges requires a multifaceted approach, combining energy efficiency, clean technology R&D, green financing, public awareness, and international collaboration to balance environmental goals with social and economic priorities (Shahzad et al., 2024).

The Greenhouse Gas (GHG) Protocol classifies emissions into three scopes: Scope 1 (direct emissions), Scope 2 (indirect emissions from purchased energy), and Scope 3 (indirect emissions across the value chain), with Scope 3 often being the largest yet most underreported category (Shrimali, 2022; Rodríguez-Jiménez et al., 2023; Brander et al., 2023). Studies show that Scope 3 accounts for 50–75% of total emissions in healthcare and up to 75% across other sectors (Rodríguez-Jiménez et al., 2023; Huang et al., 2009). Between 1995 and 2015, global Scope 3 emissions rose by 84%, with the industrial sector as the largest contributor (Hertwich & Wood, 2018). Despite their significance, many organizations struggle to report and reduce Scope 3 emissions due to complex supply chains and limited control over upstream and downstream activities (Emborg et al., 2023).

To enhance Scope 3 reporting, researchers have suggested implementing process-level GHG accounting to better identify and prioritise emission reduction opportunities (Emborg et al., 2023). Calculating Scope 3 emissions—particularly from employee commuting and business travel—remains difficult due to data variability, limited availability, and reliance on employee-reported information (Huang et al., 2009; Copeland, 2014; Grote et al., 2016). Local authorities, in particular, often face resource constraints and tend to adopt simplified or reusable models (Grote et al., 2016). In response, organisations have started using carbon calculator tools that apply standardised activity data and emission factors to streamline Scope 3 calculations (Ligafinza et al., 2024). Improvements to these tools, including more accurate emission factor specifications, have enhanced result precision. Ultimately, robust measurement of commuting emissions is vital for organisations committed to reducing their environmental impact and advancing sustainability goals (Huang et al., 2009; Copeland, 2014; Ligafinza et al., 2024).

The GHG Protocol's Corporate Standard identifies three methods for calculating employee commuting emissions: fuel-based, distance-based, and average data approaches (Tsairi & Martens, 2024). Employee commuting can be a major component of an organisation's carbon footprint—accounting for up to 60% in some cases (Pelzeterot, 2022). Studies in healthcare settings reveal that most employees commute alone by car, contributing significantly to annual emissions (Jayakrishnan et al., 2023). However, remote working has proven effective in reducing emissions, with one study showing a 97% drop during the COVID-19 pandemic (Sutton-Parker, 2021). To ensure accurate reporting, organisations are advised to regularly survey employees on commuting patterns and encourage low-emission alternatives. Promoting flexible work arrangements, raising environmental awareness, and investing in zero-carbon transport options are key strategies to sustain these reductions (Sutton-Parker, 2021).

Accurately quantifying employee commuting greenhouse gas (GHG) emissions is critical for comprehensive organizational carbon accounting. Barth & Boriboonsomsin (2009) developed detailed methodologies incorporating vehicle types and congestion to better estimate CO<sub>2</sub> reductions from traffic management. Mathez et al. (2013) demonstrated how commuting

behaviour changes significantly affect total GHG emissions. Smith (2016) highlighted inconsistencies arising from varying organizational boundary choices in GHG accounting, advocating for more comparable reporting frameworks. Monghasemi et al. (2018) showed that commute optimization tools can substantially reduce emissions, while Tsairi & Martens (2024) identified a major gap in sustainability reporting frameworks, with most failing to require specific reporting on employee commuting and transport policies.

Comparisons of data collection methods reveal that self-reported commute times tend to be overestimated versus GPS tracking, though surveys remain valuable for demographic and trip purpose insights (Kelly et al., 2013; Su et al., 2021). Combining GPS data with surveys currently offers the most reliable commuting emissions data, supported by metrics that improve survey-GPS comparability (Seaman & Young, 2012). Effective emissions accounting often integrates diverse data sources, including online surveys and big data analytics (Cook et al., 2012; Li et al., 2022). Employee commuting can constitute 7–30% of Scope 3 emissions in service sectors, underscoring its importance in carbon reduction strategies that include electric vehicle adoption and commuter incentives (Huang et al., 2009; Mathew & Kiran, 2023).

Beyond organizational methods, advances in emissions modeling—such as NTM guideline-based models, dynamic traffic assignments, inductive loop detectors, and remote sensing—have enhanced the accuracy of regional and vehicle-specific emissions inventories (Velázquez-Martínez et al., 2013; Bai et al., 2007; Jeng et al., 2013; Davison et al., 2020). However, practical application of these methods in UK local authority contexts remains underexplored. Councils like Middlesbrough face challenges including budget constraints and diverse commuting patterns, with limited guidance on choosing between distance-based and average data approaches for employee commuting emissions.

This study addresses this gap by quantitatively comparing Distance-Based and Average Data methods for Middlesbrough Council employees, assessing accuracy, practicality, and alignment with the GHG Protocol. It aims to enhance Scope 3 Category 7 emissions reporting and support net-zero policy development through detailed analysis of commuting patterns, emission contributors, and reduction strategies tailored to local government contexts.

The objectives of this study are to:

1. Collect and analyse commuting data for Middlesbrough Council employees, including transport modes, travel distances, and commuting frequency.
2. Identify key commuting patterns, data gaps, and major contributors to emissions, and propose evidence-based strategies for reduction.
3. Conduct a comparative analysis of the Distance-Based and Average Data methods in quantifying Scope 3 Category 7 emissions, using the GHG Protocol framework and UK-specific emission factors.

This study is significant because it addresses a critical gap in the practical application of employee commuting emissions quantification within UK local authorities, a context often overlooked in current research. By comparing Distance-Based and Average Data methods

specifically for Middlesbrough Council, the study provides valuable insights into the accuracy, feasibility, and suitability of these approaches for local government use. This is particularly important given the increasing pressure on councils to improve sustainability reporting and meet net-zero targets under the GHG Protocol framework. The findings will support more robust Scope 3 Category 7 emissions accounting, inform evidence-based commuting reduction strategies, and offer scalable guidance that can enhance carbon management and policy development in similar municipal contexts facing budget and logistical challenges. Ultimately, this research contributes to bridging the gap between advanced emissions methodologies and their practical implementation at the local government level, enabling more effective climate action.

## **1.2 GHG Emissions and the GHG Protocol**

Greenhouse gas emissions—mainly carbon dioxide and methane—are major drivers of global warming and climate change (Nunes, 2023; Filonchyk et al., 2024). Key sources include fossil fuel combustion, industry, agriculture, and waste (Nunes, 2023; Daeli, 2024). These gases trap heat, disrupt weather patterns, and contribute to rising sea levels, extreme weather, and ecosystem disruptions, posing significant risks worldwide (Houghton, 2005; Soeder, 2021; Wang et al., 2023; Filonchyk et al., 2024). International agreements such as the Kyoto Protocol and the 2015 Paris Agreement aim to reduce these emissions (Filonchyk et al., 2024). The GHG Protocol—developed by the WRI and WBCSD—offers globally adopted standards for organizations to measure, report, and manage emissions, supporting both internal planning and external reporting (Yaman, 2024). Mitigation strategies include improving energy efficiency, transitioning to renewable energy, and adopting carbon capture, utilization, and storage (CCUS) technologies (Houghton, 2005; Soeder, 2021; Nunes, 2023). Adaptation measures like climate-resilient infrastructure and sustainable agriculture are also essential (Daeli, 2024). While international cooperation remains vital, local implementation faces funding and capacity challenges, highlighting the need for continued innovation and global collaboration (Soeder, 2021; Daeli, 2024).

## **1.3 Organizational Challenges in Measuring Scope 3 Emissions**

The Greenhouse Gas Protocol classifies emissions into Scope 1 (direct), Scope 2 (indirect energy-related), and Scope 3 (other indirect) emissions (Rodríguez-Jiménez et al., 2023). Globally, Scope 3 emissions have grown fastest and often represent the largest share—up to 75-80%—of an organization's total carbon footprint, especially in sectors like healthcare, industry, and logistics (Hertwich & Wood, 2018; Huang et al., 2009; Annika & Blok, 2023; Suboyin et al., 2024). For example, a university's 80% of emissions were Scope 3 (Annika & Blok, 2022), and oil and gas lifecycle emissions are mostly Scope 3, expected to rise sharply (Suboyin et al., 2024). Reducing Scope 3 emissions is crucial for meeting climate targets, as they capture upstream supply chain impacts, making supplier data and sector categorization vital for accurate accounting and effective reduction strategies (Huang et al., 2009; Li et al., 2023).

While recent research emphasizes the importance of accurately quantifying Scope 3 emissions across all categories, Category 7 (employee commuting) remains underexplored across sectors

(Maximilian, 2023). Overall, empirical studies on Scope 3 reporting are limited, leading to inconsistencies in disclosures among small businesses, large organizations, and multinational firms. Even with advanced tools like machine learning, predicting Scope 3 emissions remains challenging—estimates are more accurate for upstream emissions than downstream, and category-level estimations perform better than aggregate-level ones (Nguyen et al., 2023). Key barriers include limited visibility across value chains, complex data collection, and concerns about inventory reliability (Vieira et al., 2024).

Certain Scope 3 sources—such as employee commuting and air travel—are more significant in service-based industries than in manufacturing, and reporting efforts should reflect these differences (Huang et al., 2009). However, collecting detailed data from suppliers is often hindered by legal, regulatory, interoperability, and privacy constraints (Stenzel & Waichman, 2023). Rodríguez-Jiménez et al. (2023) also found that staff travel and building infrastructure contribute 10–15% of total emissions, underscoring the need to include internal operations in Scope 3 assessments. In the transport sector, barriers to standardized emissions accounting include lack of focus on outsourced freight, poor tracking of commuting patterns, and fragmented emissions reduction strategies, often isolated within transport departments (Ellram et al., 2022). Furthermore, harmonizing emission calculations across different transport modes, especially for logistics hubs, remains difficult due to the absence of coordinated industry leadership (Dobers et al., 2019).

On average, Scope 3 accounts for over 75% of an industry's carbon footprint (Huang et al., 2009), yet accurate measurement remains elusive—especially for public sector bodies. Most research focuses on industrial and multinational contexts, with limited attention to local authorities and government organizations, where reporting practices and capacity are often weaker. Despite ongoing reporting challenges and limited academic research on Scope 3 accounting, accurately measuring Scope 3 emissions is essential for companies to evaluate their performance and plan effective sustainability strategies (Höber et al., 2024). The GHG Protocol Corporate Accounting and Reporting Standard, developed by the World Resources Institute (WRI) and the World Business Council for Sustainable Development (WBCSD), provides a comprehensive framework for reporting Scope 3 emissions—including those from employee commuting. It includes a step-by-step methodology to guide organizations in quantifying and disclosing emissions across all relevant categories.

#### **1.4 Relevance of Scope 3 Emissions Accounting for UK Local Authorities**

Local authorities in the UK play a vital role in GHG emissions, particularly across all Scope 3 categories, which encompass their entire supply chain. Employee commuting and air travel are significant contributors to emissions in the service sector, including universities (Huang et al., 2009; Hoolohan et al., 2021). However, few institutions have specific targets or action plans to substantially reduce these emissions (Hoolohan et al., 2021). While UK local authorities face challenges in implementing ambitious energy plans (Tingey et al., 2017), they have nonetheless achieved consistent GHG reductions, averaging a 31.2% decrease between 2005 and 2016 (Butt et al., 2022). Population density also strongly influences success in transportation emissions mitigation, with lower-density areas (below 25 inhabitants per hectare) underperforming in this regard (Butt et al., 2022). To advance reductions, local authorities

should promote remote working, support the electrification of personal transport in low-density areas, and integrate population density considerations into urban planning (Butt et al., 2022).

Earlier research by Revell (2013) emphasized the need for robust monitoring and evaluation of local authority sustainability programs, arguing that this would enhance understanding of their contribution to national emissions targets and improve evidence on the effectiveness of behaviour change interventions. More recently, Sudmant et al. (2022) found that if all UK local authorities meet their emissions reduction targets, their combined impact would surpass national goals, aiding achievement of the UK's 6th Carbon Budget and 2030 Nationally Determined Contribution. However, research by Allman, Lee, et al. (2024) shows that only a small number of English and Welsh local authorities have successfully developed comprehensive GHG inventories, strategies, and implemented climate adaptation and emissions reduction measures. Their success is attributed to three key factors: recognizing the secondary benefits of local climate action (e.g., job creation, improved quality of life, reduced fuel poverty), securing strong political, professional, and technical support, and overcoming financial barriers through partnerships with utilities and various sectors to fund climate initiatives (Allman, Lee, et al., 2024).

## **2.0 RESEARCH METHODOLOGY**

This section outlines the methodological framework used to assess employee commuting emissions at Middlesbrough Council, following GHG Protocol's Scope 3 Category 7 guidelines. A comparative analysis was conducted using two calculation approaches: the Distance-Based Method and the Average Data Method, selected based on data availability in line with GHG Protocol and Carbon Trust (2013) recommendations. To ensure a robust analysis, the study adopts a mixed-methods approach, integrating quantitative data (such as commuting distances and emission factors) with qualitative insights gathered through self-administered staff surveys. This combination provides a more complete understanding of commuting patterns and the behavioural factors influencing travel choices (Boodhoo & Purmessur, 2009; Park & Park, 2016). Microsoft Forms was used to collect primary data and the Excel facilitated emissions calculations and data analysis. The Distance-Based Method relied on actual employee commute data, whereas the Average Data Method utilized secondary national statistics. Middlesbrough Council was chosen as a case study due to its representative urban context and institutional commitment to sustainability. The section also outlines the procedures for sampling, data processing, emissions estimation, and homeworking calculations, along with measures taken to ensure data validity, reliability, and ethical compliance. Together, these methods provide a reliable and replicable approach for local authorities seeking to improve Scope 3 emissions reporting and develop effective carbon reduction strategies.

### **2.1 GHG Technical Guidance for Calculating Scope 3 Emissions**

According to the GHG Protocol and Carbon Trust (2013), organizations should select a calculation method for Scope 3 emissions based on data availability, using a decision tree to

guide this choice. This study applied both the Distance-Based and Average Data methods in line with these guidelines.

The Distance-Based method is preferred when detailed primary data is available, as it allows for a more precise calculation by incorporating actual travel distances, fuel types, and commuting frequency. In contrast, the Average Data method is more suitable when only generalized or secondary data is accessible, offering a simpler, broad-stroke estimation based on national averages.

Integrating both methods enhances the reliability of emissions reporting, particularly for local councils aiming to align with GHG Protocol standards. Tools such as Microsoft Forms and Excel streamline this process by enabling efficient data collection and analysis. Forms can gather essential commuting data from staff, while Excel supports calculations, visualization, and reporting.

Ultimately, using these methods in combination provides a robust and adaptable framework for accurately assessing employee commuting emissions and informing local emissions reduction strategies.

## **2.2 Case Study- The Middlesbrough Council, UK**

Middlesbrough Council was selected as the case study for quantifying employee commuting emissions due to several compelling factors. Located in Northeast England, Middlesbrough presents a unique socio-economic and urban context shaped by its transition from an industrial to a more diversified economy. Its compact size and accessibility to various transport modes—public transit, cycling, and walking—make it an ideal setting to examine complex commuting behaviours and associated emissions. Institutionally, Middlesbrough Council demonstrates a strong commitment to sustainability and environmental stewardship, providing a relevant framework to assess how local policies influence employee commuting and the council's overall emissions profile. This focus enhances the study's practical relevance and offers insight into the role of local governance in environmental outcomes.

The findings from Middlesbrough hold broader significance for other UK local authorities, as commuting patterns and emissions trends here may reflect those in similar urban areas. By adopting the methodologies and lessons from this case, other councils can improve their emissions accounting and develop targeted strategies to encourage sustainable commuting, thereby advancing national climate goals. Middlesbrough's geographical context, institutional priorities, and wider applicability make it a valuable case study. Its analysis not only deepens understanding of local authority emissions but also offers a replicable model for councils across the UK aiming to manage and reduce employee commuting emissions effectively.

## **2.3 DISTANCE-BASED METHODS**

### **2.3.1 Distance-Based Method Data Collection**

For collecting primary commute data from employees and staff of the Middlesbrough council, a Microsoft online self-completing questionnaire survey form was designed to capture the necessary data. The survey design includes a structured questionnaire focused on various data

types such as commute distance, mode, and frequency and more intricately the behavioural factors that influence commute mode choice. This study will sample responses from 100 council employees and extrapolate data as a representation of the entire workforce. Equation 1 shows the sample size determination formula used to arrive at the 100 employee sample size. The overall emissions calculated from the 100 employees surveyed is used to arrive at the per-capita emissions and multiplied by the total Middlesbrough employee count to arrive at the estimated yearly commute emissions measure in tCO<sub>2</sub>e/year.

#### Equation 1.

$$\text{Sample Size} = \frac{z^2 \times \frac{p(1-p)}{e^2}}{1 + \left( \frac{z^2 \times \frac{p(1-p)}{e^2}}{N} \right)}$$

Where:

$N$  = population size,

$e$  = Margin of error (percentage in decimal form),

$z$  = z-score,

$p$  = population size.

A sample size of 100 could easily be used for the generalization of findings while maintaining statistical extrapolation power. The sample size selection should justify a balance for the need for comprehensive data with available resources and ensure a representative cross-section of the population (Taherdoost, 2017).

#### 2.3.2 Distance-Based Method Data Analysis

Two data types were required in arriving at the total emissions generated from Middlesbrough council employees using the Distance based method. This includes commute activity data which was gotten from the direct staff sampling survey method and the emissions factor data for each mode of transport (usually expressed in units of greenhouse gas (CO<sub>2</sub>e) emitted per passenger-kilometres/mile travelled depending on transport mode).

Equation 2 is used to arrive at the total emissions for employee commuting using the Distance-based method, as expressed below and Equation 3 expresses the parameter for each commute mode emissions, e.g. Rail, Bus, Car, etc.

#### Equation 2

$$\begin{aligned} &\text{Total Emissions from employee travel} \\ &= \sum (\text{total distance travelled by vehicle type (vehicle} \\ &\quad \text{– km or passenger – km)} \times \text{vehicle} \\ &\quad \text{/mode specific emission factor (kg CO}_2\text{e/vehicle} \\ &\quad \text{– km or kg CO}_2\text{e/passenger – km)}) \end{aligned}$$

### Equation 3

*Total Emissions per Commute Mode Type*

$$= (\text{total distance travelled by Mode type (vehicle – km or passenger – km)} \times \text{vehicle specific emission factor (kg CO}_2\text{e/vehicle – km or kg CO}_2\text{e/passenger – km)}))$$

Equation 4 is used to calculate the total distance travelled a year by commute type. Cars measured in Miles and other commute options in Kilometres

### Equation 4

*Total distance travelled by Vehicle Type (vehicle – km)*

$$= \sum (\text{daily one way distance between home and work (km)} \times 2 \times 5 \times \text{number of commuting weeks per year})$$

The total emissions from employee commuting for the reporting year is calculated by a sum of emissions by the various commuting mode types. Consequently, emissions by mode type are calculated by multiplying equation 3 by each vehicle type specific emission factor as derived from the UK government ghg-conversion factors 2024 data sheet as expressed in Table 1 and 2

*Table 1: Emission Factor data table by vehicle type.*

| Size    | Motobike<br>(kg CO <sub>2</sub> e) | Type                   | Bus (kg<br>CO <sub>2</sub> e) | Type                | Rail (kg<br>CO <sub>2</sub> e) |
|---------|------------------------------------|------------------------|-------------------------------|---------------------|--------------------------------|
| Small   | 0.08319                            | Local bus (not London) | 0.12999                       | National rail       | 0.03546                        |
| Medium  | 0.10107                            | Local bus London       | 0.07447                       | International rail  | 0.00446                        |
| Large   | 0.13252                            | Average bus            | 0.10846                       | Light rail and tram | 0.02860                        |
| Average | 0.11367                            | Coach                  | 0.02717                       | London Underground  | 0.02780                        |

*Table 2: Car Emission Factor data table by fuel type.*

| Emission Factor by Car Fuel Type (kgCO <sub>2</sub> e) |         |         |         |          |
|--------------------------------------------------------|---------|---------|---------|----------|
| Size                                                   | Diesel  | Petrol  | Hybrid  | Electric |
| Small                                                  | 0.22522 | 0.23126 | 0.18143 | 0.06895  |
| Medium                                                 | 0.27050 | 0.28526 | 0.18492 | 0.07443  |
| Large                                                  | 0.33362 | 0.43267 | 0.24921 | 0.07925  |
| Average                                                | 0.27334 | 0.26473 | 0.20101 | 0.07636  |

The Car size type has been categorized as shown in the Table 3.

Table 3: Car Type Categorization by litre engine.

| Size    | Car (kg CO <sub>2</sub> e) |
|---------|----------------------------|
| Small   | Up to 1.4Litre Engine      |
| Medium  | 1.4 - 2.0 Litre Engine     |
| Large   | 2 Litre + Engine           |
| Average | Unknown Litre Engine       |

NB: Assumptions made in this calculation includes the average number of employees working week in a year as 48 working weeks/year which translates to 240 working days per year. Home working emissions were also factored into the data collection and accounting as shown in the equations below.

#### Equation 5

$$\begin{aligned}
 & \text{Total WFH Emissions per Individual} \\
 &= (\text{Total Office Electricity} * \text{Emission Factor}) \\
 &+ (\text{Total Heating Energy} * \text{Emission Factor}) \text{ kg CO}_2\text{e}
 \end{aligned}$$

#### Equation 6

$$\begin{aligned}
 & \text{Total Office Electricity} \\
 &= \left( \frac{140W * \#Homeworking FTE * WHpa}{1000} \right) \\
 &+ \left( \frac{10W * \#Homeworking FTE * WHpa}{1000} \right)
 \end{aligned}$$

#### Equation 7

$$\text{Total Heating Energy} = 1920WHpa * 5kWh * Homeworking FTE * 66.7\%$$

NB: This is calculated to be the Total Incremental gas consumption per heating year in the UK as shown in Table 4

Table 4: Homeworking Emissions Factor Table.

| Activity                                 | Unit                 | kg CO <sub>2</sub> e |
|------------------------------------------|----------------------|----------------------|
| Office Equipment                         | per FTE Working Hour | 0.03144              |
| Heating                                  | per FTE Working Hour | 0.30234              |
| Homeworking (office equipment + heating) | per FTE Working Hour | 0.33378              |

## 2.4 Average Data Method

### 2.4.1 Average Data Method Data Collection

This method uses authoritative data from the UK's Department for Energy Security and Department for Transport, providing key insights on energy use and transportation emissions in CO<sub>2</sub>e. The Department for Energy Security offers detailed energy consumption and emissions data, while the Department for Transport provides statistics on transport modes, passenger miles, vehicle types, and fuel use. The latest 2024 datasets were chosen for their accuracy, relevance, and reflection of current energy and transport trends. These government sources maintain high data quality standards, ensuring reliability. The method assumes average emission factors per person are consistent across demographics and that transport mode distribution remains stable during the study period unless affected by major policy changes. The secondary data collection relies on robust, up-to-date datasets from trusted sources, supporting an accurate analysis of UK transport-related emission factors.

### 2.4.2 Average Data Method Data Analysis

Two sets of data were collected in arriving at the total emissions generated using the Average Data Method. The Employee activity data including (number of employees, average distance travelled by an average employee per day, the average breakdown of transport modes used by employees and the average number working days per year). Secondary data set included UK emission factors for each mode of transport (usually expressed as kilograms of GHG emitted per passenger per kilometre travelled). Total Employee commute emissions is accounted for using Equation 8, derived by the summation of emissions from each mode of transport as shown below.

#### Equation 8

$$\begin{aligned} & \text{Total CO}_2\text{e emissions from employee commuting} \\ &= \sum (\text{total number of employees} \\ &\times \% \text{ of employees using mode of transport} \\ &\times \text{one way commuting distance (vehicle – km or passenger} \\ &\text{– km)} \times 2 \times \text{working days per year} \\ &\times \text{emission factor of transport mode (kg CO}_2\text{e/vehicle} \\ &\text{– km or kg CO}_2\text{e/passenger – km)}) \end{aligned}$$

NB: Assumptions made in this calculation includes the average working days in a year as 240 working days/year.

Table 5 shows the percentages of total UK employee commute by mode statistics as derived from the Transport Statistics Great Britain: 2023 Domestic Travel as published 19 December 2024. This happens to be the most recent verified data on work commute mode types in the UK.

*Table 5: Usual method of travel to work by % in Great Britain, 2023.*

| <b>Commuting Mode</b>                          | <b>UK Average Percentage %</b> |
|------------------------------------------------|--------------------------------|
| <b>Walk</b>                                    | 11%                            |
| <b>Cars and vans</b>                           | 66%                            |
| <b>Bus or Coach</b>                            | 7%                             |
| <b>Rail</b>                                    | 10%                            |
| <b>Others (Cycling and Moto Bike, Unknown)</b> | 6%                             |
| <b>Total</b>                                   | 100%                           |

(Source: UK Department of Transport, 2023)

## **2.5 Validity and Reliability of Data**

Ensuring validity and reliability in survey data collection and the use of secondary data sources is crucial for obtaining accurate and trustworthy results. In this research a clear objective has been defined to guide the survey design and ensure that the questions are relevant to the objectives being measured. Also, a validated survey instrument (Microsoft forms) has been designed and used to collect responses from participants based on its ability to report responses in a structured manner for easy and unambiguous interpretation. The questions have also been structured carefully to reflect research objectives in mind. This will go a long way to enhance responses validity, ensuring that the survey comprehensively covers and reports specific results of interest. For secondary data sources such as emissions factors, commuting mode averages and percentages, the reputation of the reporting organization, the methodology used, and the context in which the data was gathered have been carefully considered. Furthermore, in computing the data, various assumptions and uncertainties where they exist have been identified and reported accordingly.

## **2.6 Ethical Considerations**

One of the foremost ethical considerations is obtaining informed consent from participants. The data collection process ensured that the respondents fully understand the purpose of the research, the nature of their involvement, any potential risks, and their right to withdraw at any time without consequence. This information was clearly and concisely communicated through the survey questionnaire, allowing participants to make an informed decision about their participation. Confidentiality is another critical ethical aspect that was upheld throughout the research process ensuring that data collected is completely anonymized and stored securely, protecting the privacy of all participants.

### 3.0 RESULTS AND DISCUSSION

#### 3.1 Distance Based Method - Key Emissions Contributors

##### 3.1.1 Commute Mode Emissions

Table 6 shows a breakdown of emissions by commute mode offers compelling insight into the disproportionate contribution of private car use to Middlesbrough Council's employee commuting emissions. Of the total calculated emissions, car commuting alone accounted for 60.38 tCO<sub>2</sub>e/year, representing the dominant share of emissions generated. This reinforces the earlier observation of high car dependency among council staff — with 78% of respondents commuting by lone car and an additional 7% through carpooling — and aligns with existing literature identifying private vehicles as the largest contributors to commuting emissions in suburban settings (Hook et al., 2020).

Table 6: Emissions by Commute Mode

| Commute Mode | Emissions by Commute Mode (tCO <sub>2</sub> e/year) |
|--------------|-----------------------------------------------------|
| Car          | 60.38                                               |
| Rail         | 0.54                                                |
| Bus          | 0.18                                                |
| Moto Bike    | 0                                                   |
| Bicycle      | 0                                                   |
| WFH          | 29.28                                               |

In contrast, rail travel contributed only 0.54 tCO<sub>2</sub>e/year, while bus commuting accounted for just 0.18 tCO<sub>2</sub>e/year, despite both being more sustainable alternatives. This disparity could be attributed to limited accessibility, lower frequency of service, or personal preferences for the convenience and flexibility of car travel. Notably, motorbike and bicycle commuting resulted in zero emissions in this dataset, likely indicating that these modes are either underutilised or entirely absent among the sampled employees. This suggests an opportunity for policy intervention to incentivise active travel modes, especially for employee short-distance commuters. Moreover, working from home (WFH) was responsible for 29.28 tCO<sub>2</sub>e/year, underscoring that remote work, while reducing travel-related emissions, still carries a measurable carbon footprint due to increased residential energy use. These findings emphasize the need for Middlesbrough Council to balance hybrid working benefits with energy efficiency measures and to prioritize sustainable transport alternatives to curb the overwhelming emissions impact of car travel.

##### 3.1.2 Car Fuel Type Emissions

In Table 7, a closer examination of emissions by car fuel type reveals the significant impact that fuel choice has on overall commuting emissions within Middlesbrough Council. An analysis of the distribution of car fuel types among staff respondents reveals a strong correlation between vehicle prevalence and total emissions contribution. Out of 87 car users, 55 (63%) reported using petrol vehicles, 23 (26%) used diesel, 7 (8%) electric, and only 2 (2%) hybrid vehicles. This composition aligns closely with the emissions profile observed earlier, where petrol cars were responsible for the highest emissions at 34.06 tCO<sub>2</sub>e/year, followed by diesel cars at 23.67 tCO<sub>2</sub>e/year.

Table 7: Car Emissions by Fuel Type

| <b>Fuel Type</b> | <b>Emissions by Car Fuel Type (tCO<sub>2</sub>e/year)</b> |
|------------------|-----------------------------------------------------------|
| <b>Petrol</b>    | 34.057                                                    |
| <b>Diesel</b>    | 23.668                                                    |
| <b>Electric</b>  | 2.162                                                     |
| <b>Hybrid</b>    | 0.491                                                     |

This is consistent with national trends in vehicle ownership and the continued reliance on internal combustion engines in suburban areas, particularly where public transport infrastructure is limited (Department for Transport, 2024). Despite diesel engines typically offering better fuel efficiency, their emission profiles — especially in terms of nitrogen oxides (NO<sub>x</sub>) — still pose significant environmental challenges, and their lower CO<sub>2</sub>e here is more reflective of vehicle usage patterns than emission factor superiority. In contrast, electric vehicles (EVs) were responsible for just 2.16 tCO<sub>2</sub>e/year, showcasing their potential in significantly reducing commuting-related emissions, especially when charged using low-carbon electricity. Hybrid vehicles contributed even less, at 0.49 tCO<sub>2</sub>e/year, reflecting both their improved fuel economy and their minimal representation in the dataset. These figures underscore a critical opportunity for Middlesbrough Council to support and accelerate the transition to low-emission vehicles among staff. By providing EV incentives, expanding charging infrastructure, and embedding sustainability into fleet and travel policies, the council can substantially reduce its Scope 3 Category 7 emissions. Overall, the current dominance of petrol followed by diesel cars reinforces the necessity of targeted interventions aimed at behavioural change and vehicle decarbonisation to meet local and national Net Zero targets.

The high emissions from petrol vehicles can be attributed not only to their dominance in the commuting fleet but also to their relatively higher carbon intensity per litre of fuel consumed, as outlined by the Department for Environment, Food and Rural Affairs (DEFRA) emission conversion factors (Department for Energy Security and Net Zero, 2024). While diesel vehicles are fewer in number, their collective emissions are still significant, indicating moderate distances travelled and less efficiency in real-world driving conditions. On the other hand, electric vehicles, despite representing 8% of the commuting fleet, account for only 2.16 tCO<sub>2</sub>e/year, highlighting their role as a low-emission alternative. Hybrid vehicles, with only two users, produced just 0.49 tCO<sub>2</sub>e/year, reflecting both their efficiency and limited uptake. This pattern underscores the potential emission reduction benefits of shifting employee vehicle use from petrol and diesel to electric or hybrid models. For Middlesbrough Council, this data presents a compelling case for promoting low-emission vehicle schemes, such as EV salary sacrifice programs, workplace charging stations, and targeted awareness campaigns to drive adoption of cleaner commuting alternatives.

### 3.1.3 Per-Capita Emissions

The calculated per-capita commuting emission of 0.9 tCO<sub>2</sub>/year provides a useful benchmark for evaluating the carbon intensity of staff travel behaviour at Middlesbrough Council. This figure, while modest in isolation, becomes more significant when multiplied across the council's entire workforce and considered in the context of carbon budgets and local climate targets. This figure when compared with the average commuter carbon footprint of 0.62 tCO<sub>2</sub>e per person per year from the National Travel Survey, Department for Transport (DfT) (2023)

could be validated by the relatively high reliance on private car use (85% of all respondents, including lone and shared car use)—especially petrol (63% of car users) and diesel vehicles within the Middlesbrough context which greatly contributes to this intensity. These vehicle types are known to have higher emissions factors compared to low-emission alternatives like electric vehicles or public transport. In contrast, low-carbon or zero-emission commuting options, such as walking, cycling, or full-time remote work, are minimally represented in the data and thus do not significantly pull down the overall per-capita emissions.

The implication here is clear, the carbon footprint per employee is heavily shaped by mode choice and work patterns. For instance, an employee commuting five days a week via a petrol car may emit well above the average, while one working mostly from home or cycling may fall well below. This uneven distribution indicates opportunities for targeted interventions—encouraging behavioural shifts such as carpooling, modal shifts to public transport, or hybrid work policies—to reduce individual and collective emissions. In broader terms, per-capita commuting emissions serve not only as a performance indicator but also as a guidepost for climate action planning, revealing how individual mobility choices scale into organisational climate responsibility. Given Middlesbrough Council's ambition to improve Scope 3 reporting, lowering this per-capita metric through inclusive and sustainable transport policies could become a key climate action goal.

3.1.4 Emissions by Car Engine Size

Another analysis breaks down estimated emissions by car engine size, revealing a clear and expected pattern: larger engine sizes are associated with higher emissions per vehicle, reinforcing the role of vehicle specifications in determining commuting carbon intensity. The categorization of cars by engine size is summarized in Figure 1.

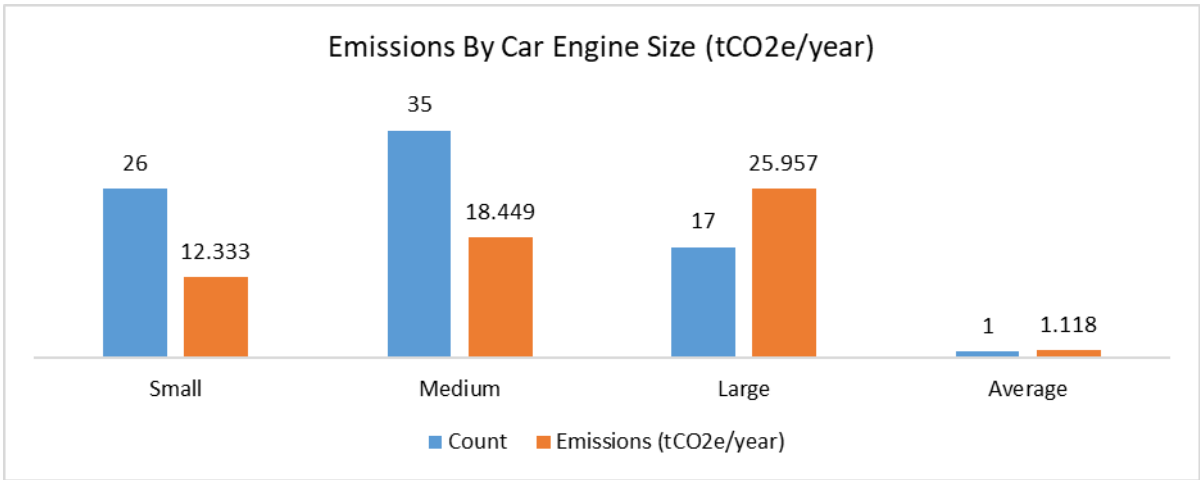


Figure 1: Graph showing the Emissions Generated by Car Engine Size.

As seen in Table 8, Among the 79 respondents who commute by lone car, small engine vehicles (n = 26) contributed 12.33 tCO<sub>2</sub>e/year, medium engines (n = 35) generated 18.45 tCO<sub>2</sub>e/year, while large engines (n = 17) produced the highest emissions, totalling 25.96 tCO<sub>2</sub>e/year. Although fewer in number, large engine vehicles disproportionately contribute to overall commuting emissions, highlighting the carbon inefficiency of such vehicles. The single response for "average" engine size generated 1.12 tCO<sub>2</sub>e, which, though minimal, cannot be

interpreted meaningfully due to the small sample size. The dominance of medium and large engine vehicles (66% combined) suggests that vehicle engine capacity is a critical factor in emissions profiling within the council workforce, potentially exacerbating the environmental impact of already high car dependency.

Table 8: Emissions by Car Engine Size

| Car Engine Size | Count | Emissions<br>(tCO <sub>2</sub> e/year) |
|-----------------|-------|----------------------------------------|
| <b>Small</b>    | 26    | 12.333                                 |
| <b>Medium</b>   | 35    | 18.449                                 |
| <b>Large</b>    | 17    | 25.957                                 |
| <b>Average</b>  | 1     | 1.118                                  |

This pattern further underscores the importance of vehicle downsizing or transitioning to low-emission vehicle alternatives in efforts to lower Scope 3 commuting emissions. For instance, even if employees continue to use personal vehicles, encouraging the adoption of smaller engine sizes, hybrid, or electric vehicles could result in measurable reductions. In policy terms, this data supports the case for fleet emission standards, targeted incentives for lower-emission vehicles, and education campaigns on the environmental and financial benefits of smaller engine options. For Middlesbrough Council, engaging staff around these options could significantly reduce carbon intensity without requiring complete shifts away from car usage.

### 3.1.5 Employee One-Way Commute

The analysis of employee one-way commute distances reveals a significant correlation between travel distance and total commuting emissions, even when longer commutes are less common. The majority of employees (57%) fall into the medium-distance bracket (5–25 miles), collectively contributing 43.60 tCO<sub>2</sub>e/year, which represents the bulk of the emissions from commuting. This dominance underscores how moderate-distance commuting, especially when done frequently and via petrol or diesel-powered vehicles, is a major driver of cumulative emissions. Employees commuting short distances (0–5 miles)—the second-largest group (n = 33)—generated significantly lower emissions, just 7.05 tCO<sub>2</sub>e/year, illustrating how proximity to the workplace can meaningfully reduce individual and collective carbon footprints. Conversely, although only 5 employees reported long-distance commutes (25+ miles), their emissions totalled 10.32 tCO<sub>2</sub>e/year, an average of over 2 tCO<sub>2</sub>e per person, indicating a high carbon intensity per capita for this group as seen in Figure 2.

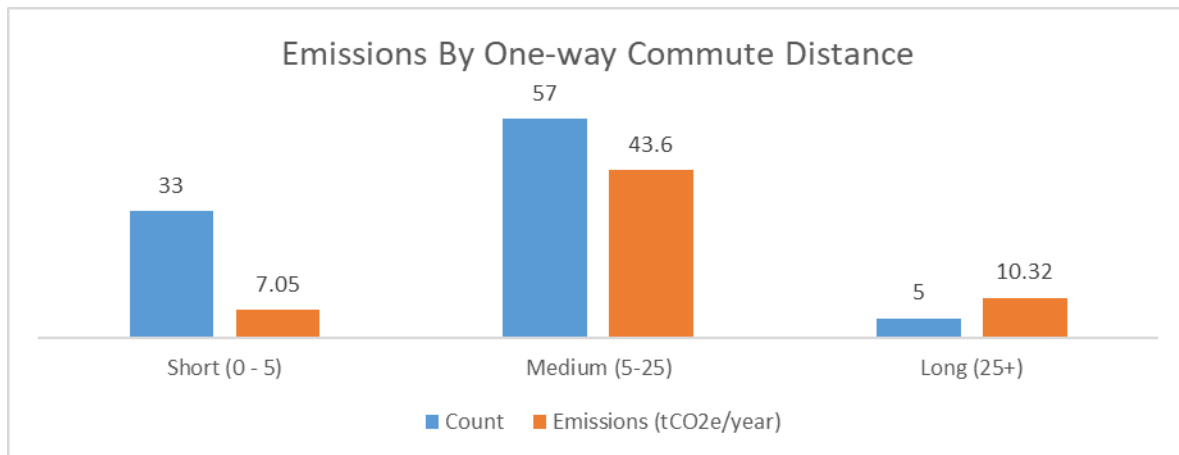


Figure 2: Graph showing the Employee One-way commute Distance vs Emission

This pattern illustrates how both the frequency and distance of travel compound emission outputs, and it strengthens the argument for remote or hybrid working policies, especially for long-distance commuters. It also demonstrates the need for place-based commuting strategies, such as encouraging relocation incentives, promoting park-and-ride schemes, or investing in inter-town low-carbon transit for longer-distance staff. Alternatively, Location as a factor could be introduced into long term hiring considerations by the Human Resource team. For Middlesbrough Council, the data confirms that while reducing long-distance commuting is important, addressing the medium-distance group, which constitutes the largest emitter cohort, should be a key priority for effective Scope 3 Category 7 mitigation.

### 3.1.6 Car Commute days per week

An analysis of emissions based on the number of car commute days per week as seen in Table 9, reveals a predictable but important relationship between commuting frequency and carbon output. As expected, employees who commute five days a week by car, irrespective of type or engine type contribute the highest total emissions, amounting to 25.32 tCO<sub>2</sub>e/year, which reflects both the intensity and frequency of travel. Interestingly, emissions from those commuting two days per week (12.90 tCO<sub>2</sub>e/year) surpass those commuting three or four days (10.24 and 7.66 tCO<sub>2</sub>e/year, respectively). This apparent deviation from the expected linear trend may suggest that employees commuting fewer days are doing so over longer distances or using more carbon-intensive vehicles, such as those powered by diesel or large petrol engines. Similarly, the lowest emissions (4.26 tCO<sub>2</sub>e/year) are recorded among those commuting only one day per week, highlighting the value of flexible and hybrid work arrangements in reducing overall travel-related emissions.

Table 9: Cars Commuting Days a week vs Emissions

| Car Commute Days/Week | Emissions (tCO <sub>2</sub> e/year) |
|-----------------------|-------------------------------------|
| 1                     | 4.26                                |
| 2                     | 12.90                               |
| 3                     | 10.24                               |
| 4                     | 7.66                                |
| 5                     | 25.32                               |

These findings reinforce the importance of considering both commuting frequency and commute distance when designing policies aimed at cutting Scope 3 Category 7 emissions. For instance, simply reducing the number of office days may not yield proportional emission reductions unless paired with targeted interventions like promoting carpooling, encouraging modal shifts, or prioritising lower-emission vehicles. For Middlesbrough Council, this insight underscores the need for more granular travel data and employee-specific support strategies that factor in both travel frequency and distance to effectively curb emissions from daily commutes.

## 3.2 BEHAVIOURAL ANALYSIS

The Survey also captured behavioural insights that could affect directly or indirectly affect emissions generation

### 3.2.1 Factors that influence the choice of commuting mode

The survey responses regarding factors influencing the choice of commuting mode revealed that convenience is the dominant consideration by employees, cited by 79 respondents indicating that most employees price their personal spaces and privacy above all other factors to consider. Followed by travel time (50) and cost (33) as seen in Figure 3. This indicates that for the majority of Middlesbrough Council employees, commuting decisions are driven primarily by how easy and efficient the travel experience is, rather than by environmental concerns or economic cost alone. Despite ongoing national climate goals and organisational sustainability ambitions, only 6 respondents selected environmental impact as a key factor, suggesting a gap between personal commuting decisions and environmental awareness. This insight is consistent with previous study which show that without institutional support or incentives, individuals are less likely to prioritise environmental considerations in their daily travel routines. (Hook et al., 2020).

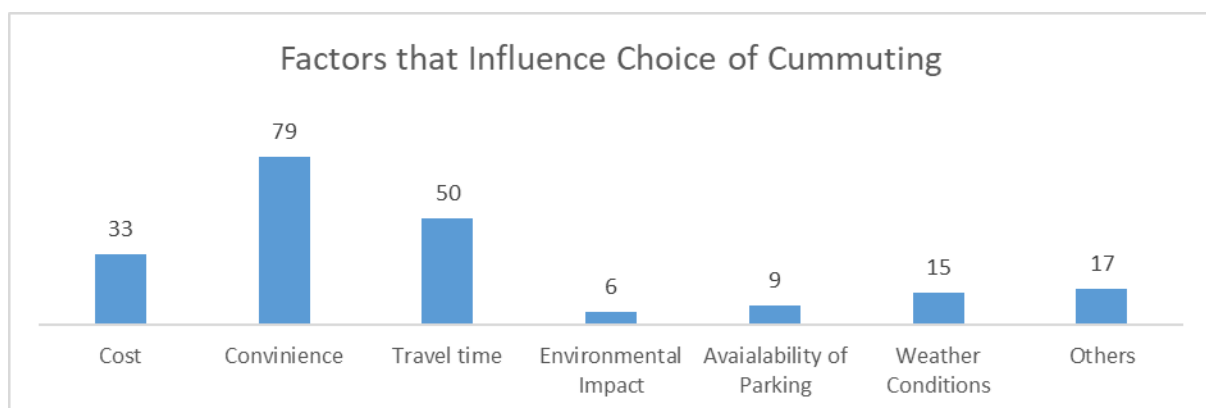


Figure 3: Graph showing the Car Emissions by No of Commute Days a week

Other less commonly cited factors included weather conditions (15), parking availability (9), and other reasons (17), potentially including childcare responsibilities, personal safety, or physical ability—issues not fully captured in this data but worth exploring in future research. These findings have important implications for emissions reduction strategies. If convenience

and time efficiency dominate decision-making, then sustainability policies must align with those priorities—by improving the convenience of lower-emission options such as public transport or cycling, and by reducing the travel time penalties associated with them. For example, Middlesbrough Council could consider enhancing EV infrastructure, supporting flexible scheduling, or offering subsidised transit options to encourage modal shift without compromising convenience.

### 3.2.2 Willingness to switching to a more sustainable mode of transport?

The survey results indicate a mixed outlook regarding the willingness of Middlesbrough Council employees to adopt more sustainable commuting practices. Out of 100 respondents, 28% answered “Yes”, expressing a clear willingness to transition to more environmentally friendly transport modes. Meanwhile, 30% responded “No,” indicating a firm resistance or possible constraints—such as availability, distance, or personal responsibilities—that inhibit such change as seen in Figure 4. The largest proportion, however, 42%, selected “Maybe,” reflecting a sizeable segment of the workforce that is open to change but remains undecided. This group represents a strategic target for policy intervention. Their indecision could stem from practical concerns such as the inconvenience of public transport routes, inadequate cycling infrastructure, or the higher initial costs of electric vehicles.

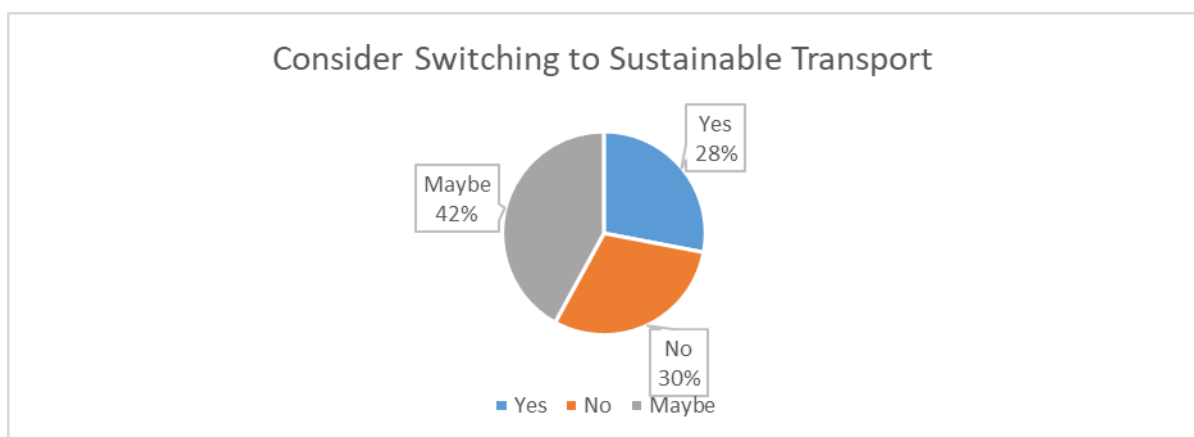


Figure 4: Graph showing employee willingness to switch to a more Sustainable transport Mode

These findings are critical for policy development. The high number of undecided respondents suggests that with the right incentives—such as EV salary sacrifice schemes, subsidised public transport passes, safe bike storage, or guaranteed ride-home programs—many employees could be encouraged to transition away from lone car use. Behavioural change literature (e.g., Sheppard, 2023) supports the idea that a supportive policy environment, combined with visible infrastructure improvements and workplace culture shifts, can tip “maybe” responses into “yes.” Therefore, Middlesbrough Council’s carbon reduction strategy should prioritise low-barrier, high-visibility incentives to sway this pivotal middle group and achieve meaningful modal shifts in commuting behaviour.

### 3.2.3 Factors that would encourage you to adopt a more sustainable commute practice?

In response to the question regarding factors that would encourage a shift toward more sustainable commuting practices, the data reveals a strong demand for systemic and institutional support mechanisms. The most frequently selected factor was “Improved Public Transport Options” with 41 respondents, underscoring the critical role of accessible, reliable, and efficient public transport in shaping commuting decisions. This aligns with broader findings in sustainable transport literature, which consistently identify public infrastructure as a cornerstone for behavioural change (Niedderer et al., 2016). “Subsidised travel passes” were also cited by 27 respondents, suggesting that financial incentives could lower the perceived cost barrier to switching modes—particularly relevant in the context of rising living and fuel costs.

Table 10: Factors that would encourage a switch to a more Sustainable transport Mode

| <b>What factors would encourage you to adopt a more sustainable commute practice?</b> | <b>Count</b> |
|---------------------------------------------------------------------------------------|--------------|
| <b>Improved Public Transport Option</b>                                               | 41           |
| <b>Subsidised travel passes</b>                                                       | 27           |
| <b>Workplace Carpooling Scheme</b>                                                    | 17           |
| <b>More Flexible Working Arrangements</b>                                             | 23           |
| <b>No Factor can encourage me adopt a more sustainable commuting practice</b>         | 28           |
| <b>Others</b>                                                                         | 11           |

As shown in Table 10, workplace-based solutions also garnered attention, with 17 respondents indicating that a formal carpooling scheme could positively influence their commuting choices. This suggests untapped potential in peer-supported low-carbon options, which could be operationalised with digital platforms or internal incentive schemes. Additionally, 23 staff members selected “More Flexible Working Arrangements,” reinforcing the growing relevance of hybrid work models as indirect enablers of sustainable commuting—either by reducing travel frequency or allowing shifts to less congested travel times. However, 28 respondents selected “No factor can encourage me,” indicating a significant resistance or structural immobility—possibly due to long commute distances, caregiving obligations, or strong car dependence. This group may require more tailored interventions, including long-term educational campaigns or major infrastructural changes to alter entrenched behaviours.

In summary, while infrastructural and financial interventions hold promise for encouraging sustainable commuting at Middlesbrough Council, they must be paired with behavioural nudges, internal policy reform, and ongoing employee engagement to fully realise modal shift ambitions.

## 3.3 STRATEGIC PATHWAYS TO SUPPORT SUSTAINABLE TRAVEL ACROSS MIDDLESBROUGH COUNCIL

This section outlines suggestions on how Middlesbrough Council can reduce its employee commute emissions. Based on 100 open-ended staff responses, seven key areas for action have been identified. These cluster into six broad themes as seen in Table 11, highlighting where employees believe the Council can most effectively drive change.

Table 11: Factors that would support sustainable travel across Middlesbrough Council.

| Theme                                                                             | Indicative comments (verbatim)                                                                                                                                                                  | Approx. no. of mentions |
|-----------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------|
| <b>1. Better Public-Transport Offer</b>                                           | “Cheaper, more regular bus and train journeys”; “Transport links from Great Ayton, Stokesley and Nunthorpe are dire... a dedicated bus that gets you directly to town... could be a nice idea.” | ≈25                     |
| <b>2. More Home / Hybrid Working</b>                                              | “Allow everyone to just have 1 office day a week and the rest at home”; “Increase the number of days we can work from home to 5.”                                                               | ≈20                     |
| <b>3. Financial &amp; Workplace Incentives (fares, EV schemes, carpool perks)</b> | “Reduced salary-sacrifice scheme for electric vehicles, average cost is over £400 per month”; “Offer guaranteed parking spaces for car-pooling.”                                                | ≈18                     |
| <b>4. Cycling &amp; Active-Travel Infrastructure</b>                              | “Better cycle lanes and start cycling groups for health-and-well-being”; “Some of the cycle paths... need to be resurfaced.”                                                                    | ≈12                     |
| <b>5. EV &amp; Charging Infrastructure</b>                                        | “More charging points so more people choose electric”; “Better EV charging to encourage electric-vehicle use.”                                                                                  | ≈10                     |
| <b>6. Parking &amp; Fleet Policies</b>                                            | “Increase parking charges/enforcement”; “Stop employees using work vans for work/home commute.”                                                                                                 | ≈8                      |

### Systemic Transport Fixes First: Prioritising Public Transport Improvements

The most frequently cited recommendation from council staff relates to the need for a significantly better public transport system. Approximately 25 of the open-ended responses mentioned issues such as irregular scheduling, limited routes, and high costs. For example, one staff member highlighted that the current train fare (£13) is more than double the cost of driving (£6), which discourages environmentally-friendly commuting. Others noted that existing bus and train services are unreliable or fail to align with typical working hours, stating, “the timetable doesn’t always fit with a general work day.” These issues are particularly acute for employees living in poorly connected areas like Great Ayton, Stokesley, and Nunthorpe, where direct public transport options are either limited or non-existent. This aligns with the broader quantitative findings, which indicate that convenience and travel time are more influential in mode choice than environmental concern. For Middlesbrough Council, this suggests a clear opportunity to work with regional transport authorities to improve service frequency, reduce travel costs for staff, and explore new direct or express routes to underserved locations. Enhancing real-time travel information and integrating smarter ticketing systems could further increase public transport appeal and help shift commuter habits in a more sustainable direction.

### **3.3.1 Hybrid Working Still Under-Exploited: Increasing Remote Work Flexibility**

A significant portion of respondents—around 20 individuals—expressed a desire for more extensive home and hybrid working arrangements. Comments such as “allow everyone to just have 1 office day a week and the rest at home” and “increase the number of days we can work from home to 5” suggest that many employees feel the current hybrid model is unnecessarily restrictive. This feedback is supported by emissions data showing that employee commuting generates approximately 0.9 tonnes of CO<sub>2</sub> equivalent per person annually. By reducing the number of mandatory office days, the Council could achieve quick, measurable reductions in emissions without disrupting operational performance. In fact, employees themselves believe that greater flexibility can be offered with minimal harm to productivity or service delivery. As such, Middlesbrough Council should reassess departmental attendance policies and consider expanding remote work eligibility, especially for roles that are already effectively performed from home. This could be complemented by clearer guidelines, digital tools, and training to support managers and teams in maintaining engagement and accountability in a hybrid environment.

### **3.3.2 Targeted Incentives to Convert the ‘Maybe’ Group**

One of the most actionable insights from the staff responses is the potential to influence the large “Maybe” group—42% of employees who indicated they might switch to greener commuting options under the right conditions. Around 18 responses specifically recommended financial and practical incentives to make low-carbon commuting more attractive. Suggestions included the introduction of reduced-cost electric vehicle (EV) salary-sacrifice schemes, subsidised public transport passes, and preferential parking for carpoolers. These incentives directly target the barriers holding many staff back, such as cost and convenience. If Middlesbrough Council can implement a well-structured, tiered package of benefits—tailored to different commuting needs—it could help tip the balance for this undecided group. Beyond financial savings, highlighting the personal and environmental benefits of alternative commuting methods through internal campaigns could further encourage uptake. In essence, relatively small, targeted interventions could unlock a significant portion of emissions savings if designed and promoted effectively.

### **3.3.4 Supporting Active Travel through Infrastructure Investment**

Encouraging staff to walk or cycle to work, particularly those living within five miles of their workplace, could significantly reduce commuting emissions—currently 7 tonnes of CO<sub>2</sub>e annually from this short-distance group alone. However, around 12 staff responses point to existing infrastructure as a barrier to active travel. Common issues include poor-quality or incomplete cycle lanes, lack of safety on certain routes, and insufficient facilities such as showers, lockers, or bike storage. Staff suggested practical improvements like resurfacing cycle paths and organising cycling groups to support healthier commuting options. To make walking and cycling viable alternatives, the Council needs to align infrastructure upgrades with broader health and wellbeing initiatives. For example, capital improvement projects could prioritise commuter routes that also serve as recreational paths, while workplace wellness programmes

could offer incentives for active travel. By making these modes both practical and desirable, the Council could shift a significant number of short-distance car users to zero-emission alternatives.

### **3.3.5 Scaling Up EV and Charging Infrastructure**

Electric vehicle adoption is another area where the Council could drive positive change, but it requires addressing the current lack of charging infrastructure. Around 10 respondents explicitly stated that limited availability of charging points discourages them from considering an EV. Some recommended that the Council invest in additional workplace charging stations and offer dedicated staff access to encourage adoption. Others pointed out the need for more affordable EV leasing options, noting that the average cost of current salary-sacrifice schemes exceeds £400 per month. To foster greater EV uptake, the Council should consider expanding its charging infrastructure, particularly at major office locations, and negotiating more competitive salary-sacrifice arrangements. Furthermore, educational efforts to dispel myths and provide information on EV costs, efficiency, and charging options could help bridge the knowledge gap. Supporting staff through both infrastructure and financial tools would make EVs a more realistic and attractive commuting choice.

### **3.3.6 Revising Parking and Fleet Policies for Behavioural Change**

Although mentioned less frequently—by approximately eight staff—parking and fleet policy reforms still represent a strategic tool for shifting commuting behaviours. Some staff suggested increasing parking charges or tightening enforcement to discourage solo car use. Others recommended restricting the use of Council vehicles, such as work vans, for commuting unless necessary for job functions. These proposals hint at the potential effectiveness of well-calibrated disincentives in reducing emissions, particularly when combined with positive alternatives like carpooling perks. Middlesbrough Council could pilot these changes in a few departments to evaluate their impact and staff acceptance. For example, a carpool priority parking scheme could run alongside a gradual increase in parking costs for single-occupancy vehicle users. Similarly, clearer policies around fleet vehicle use could ensure that Council-owned vehicles are used efficiently and in line with environmental targets. These interventions require careful communication and staff engagement to avoid backlash, but they could play a valuable role in a broader emissions reduction strategy.

### **3.3.7 Addressing Policy Resistance and Structural Barriers**

It's important to acknowledge that not all staff are in a position to change how they commute. A significant minority—28%—indicated that no policy or incentive would influence their current travel behaviour. This group often cited constraints beyond the Council's control, such as childcare responsibilities, mental health concerns, or the unavailability of viable public transport. Comments like “public transport is out of my control” illustrate how deeply structural some of these issues are. While it may not be possible to fully shift this group in the short term, the Council can still support them by offering personalised solutions or recognising their needs in policy development. For example, flexible start times could help staff with childcare responsibilities avoid peak commuting periods, while mental health support initiatives could

be tied to remote working options. Understanding and respecting these constraints is essential to building inclusive, fair, and effective commuting policies.

### 3.4 BARRIERS TO ADOPTING MORE SUSTAINABLE COMMUTING MODES

Understanding the barriers to sustainable commuting is essential for designing effective interventions that align with the lived experiences of employees. In response to the question, Middlesbrough Council staff identified a range of structural, economic, and personal factors that constrain their travel choices. These responses, visualised in Figure 5, reflect complex and often overlapping challenges that hinder modal shift away from private car use. This section discusses the key themes that emerged, offering insight into both the frequency and nature of these constraints.

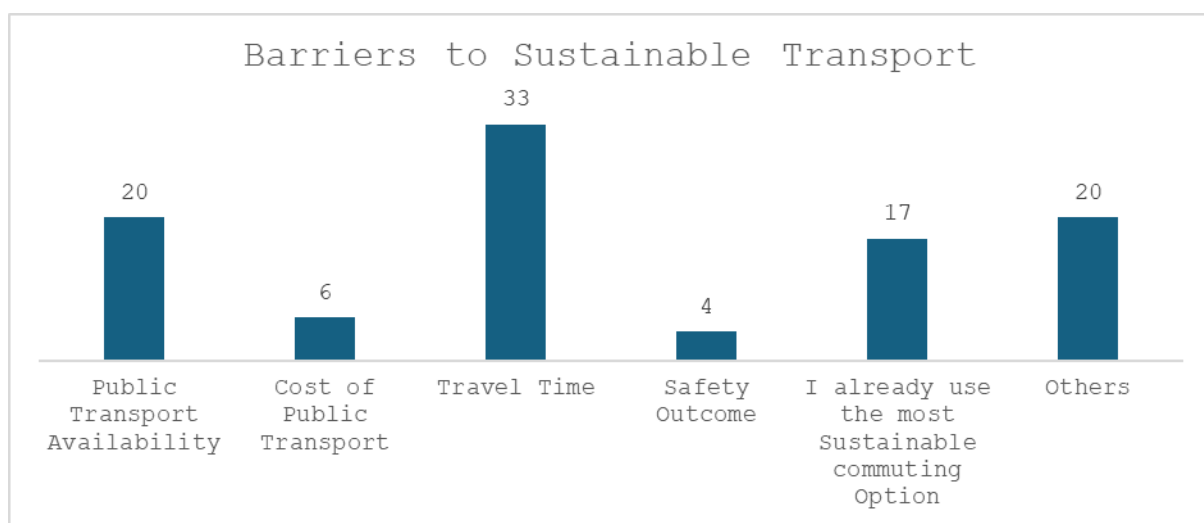


Figure 5: Graph of Barriers to Employees' Sustainable Transport Adoption

The most commonly reported barrier was excessive travel time, mentioned by 33 respondents (33% of the total). This finding highlights the dominant role that convenience and efficiency play in commuting decisions. Sustainable modes such as buses or trains are often perceived as significantly slower than car travel, particularly when public routes involve multiple stops, transfers, or indirect paths. One respondent summed this up by stating, *"The bus route (29) takes you through every estate going and takes a lifetime."* Such delays can make sustainable travel appear impractical, even for those who might otherwise be motivated by environmental concerns. This indicates that without improvements to journey times and directness, modal shift is likely to remain limited.

Poor availability and connectivity of public transport emerged as the second most cited barrier, affecting 20 respondents. This is particularly salient for staff living in outlying villages or low-density areas where service provision is limited. The lack of direct routes, infrequent schedules, and poor integration between different modes (e.g., bus to train) make it difficult for employees to rely on public transport for daily commuting. These findings are consistent with earlier qualitative responses, where staff highlighted the inadequacy of links from areas like Great

Ayton and Stokesley. The Council's dependence on car-based travel infrastructure is thus reinforced by the absence of viable alternatives.

While fewer in number, six respondents identified cost as a key deterrent to public transport use. In some cases, the comparative cost of a car journey versus a train or bus was seen as unjustifiable, with one respondent stating, "*£6 for a car journey, £13 for a train.*" This economic disincentive reflects a broader structural issue: that the current pricing model for public transport does not reflect its societal benefits in terms of emissions reduction. For lower-income employees, the financial trade-off may be especially burdensome. Subsidised fares, corporate travel schemes, or salary-sacrifice transport options could play a role in addressing this imbalance and encouraging uptake.

Safety-related barriers were cited by four respondents, particularly in relation to active travel modes like walking and cycling. Issues included concerns about poorly maintained cycle paths, lack of lighting, and general road safety. Although numerically small, this group reflects important infrastructure gaps that could significantly deter broader adoption of active travel. In addressing these concerns, the Council should consider capital investments in well-lit, segregated cycle routes and enhanced pedestrian infrastructure as part of a broader strategy to promote active commuting.

Encouragingly, 17 respondents reported that they were already using the most sustainable commuting mode available to them. These individuals are likely to be walking, cycling, using electric vehicles, or working from home. While this segment may not represent an immediate opportunity for modal shift, their responses confirm the presence of a motivated and environmentally conscious cohort within the workforce. This group could serve as internal advocates or role models, supporting culture change and peer influence efforts across departments.

The final group, comprising 20 respondents, pointed to a variety of other reasons that hinder sustainable commuting. These include health conditions, disabilities, childcare responsibilities, and job roles that require the use of a private vehicle—such as social workers on call or staff transporting equipment. These individualised or role-specific constraints highlight the importance of flexibility in policy design. One-size-fits-all solutions are unlikely to be effective, and blanket mandates may inadvertently penalise those facing legitimate barriers. Instead, tailored interventions, such as allowing partial remote work or providing accessible parking only to essential users, may be more appropriate.

### **3.5 AVERAGE DATA METHOD**

#### **3.5.1 Commute Mode Emissions**

The Average Data Method offers a streamlined approach to estimating emissions from employee commuting by relying on national-level modal split percentages published by the UK Department for Environment, Food and Rural Affairs (DEFRA). According to this data, 66% of commuters nationally travel by cars and vans, 11% walk, 10% use rail, 7% travel by bus or coach, and 6% use other modes such as cycling or motorbikes as presented in Table 12 below.

Table 12: UK National Average Commute Data

| Commuting Mode                 | Percentage % |
|--------------------------------|--------------|
| Walk                           | 11%          |
| Cars and vans                  | 66%          |
| Bus or Coach                   | 7%           |
| Rail                           | 10%          |
| Others (Cycling and Moto Bike) | 6%           |
| Total                          | 100%         |

The emissions profile produced using the Average Data Method, based on UK DEFRA modal percentages, is shown in Figure 6, this method offers a generalized national picture that masks significant local variation. Using this method, commuting by cars and vans alone accounts for an overwhelming 738.75 tCO<sub>2</sub>e/year, or approximately 91% of total emissions (811.47 tCO<sub>2</sub>e/year). This aligns with DEFRA’s national commuting statistic of 66% car use, though it underrepresents the local survey’s finding of 78% lone car travel, a misalignment that likely contributes to the underestimation of emissions when compared to the Distance-Based Method.

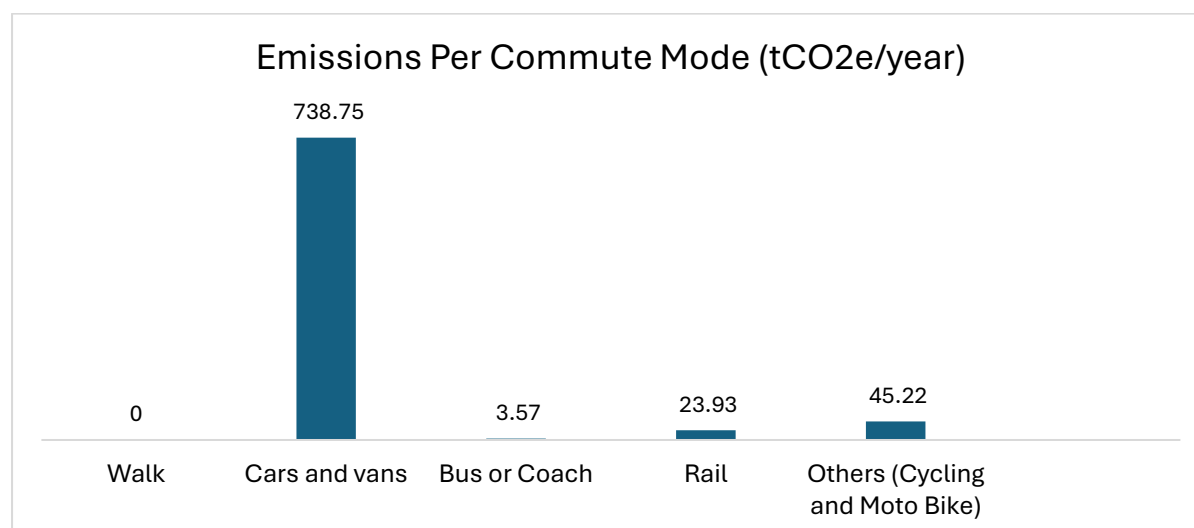


Figure 6: Graph of Emissions by commute mode using the Average Data Method

Notably, the Average Data Method attributes 0 tCO<sub>2</sub>e/year to walking, consistent with its zero-emission nature. However, bus or coach travel accounts for only 3.57 tCO<sub>2</sub>e/year, and rail for 23.93 tCO<sub>2</sub>e/year, jointly making up less than 4% of total emissions. These figures may appear low, but they result from both low emissions intensity per passenger kilometer and relatively low national modal shares (7% and 10%, respectively). Interestingly, “Others” (cycling and motorbike) contributes 45.22 tCO<sub>2</sub>e/year — a surprising figure given their combined 6% national modal share. This likely reflects the inclusion of motorcycles in this group, which, unlike bicycles, emit carbon. Yet, the method lacks precision in separating active zero-emission modes (e.g., cycling) from low-volume but carbon-emitting modes (e.g., motorbikes), thereby obscuring the role of sustainable transport.

Comparatively, the Distance-Based Method attributes 829.01 tCO<sub>2</sub>e/year to cars — nearly 90.6 tCO<sub>2</sub>e more than the Average Method — suggesting that national averages significantly downplay the emissions impact in highly car-dependent regions like Middlesbrough.

Additionally, modes like rail and bus, though important nationally, played only marginal roles in the local context, each used by less than 6% of the survey respondents. This highlights the structural transport inequalities between urban centres and more suburban or rural councils.

### 3.6 METHOD COMPARISON AND LOCAL-CONTEXT EMISSIONS GAPS: COMMUTE MODAL DISTRIBUTION

The comparative distribution of commute modes between the Distance-Based Method (survey data) and the Average Data Method (DEFRA national averages) reveals substantial differences that underscore the limitations of applying national assumptions to local carbon accounting. As seen in Figure 7, comparatively, the Distance-Based Method attributes 829.01 tCO<sub>2</sub>e/year to cars — nearly **90.6 tCO<sub>2</sub>e** more than the Average Method as shown in Figure 8, this suggests that national averages significantly downplay the emissions impact in highly car-dependent regions like Middlesbrough. Most notably, car (alone) usage stands at 78% in Middlesbrough Council’s employee dataset, compared to just 66% in the national average. This 12% increase reflects the town’s higher car dependency, likely influenced by many individual or local factors as reflected by the employee survey responses such as suburban infrastructure, limited public transport coverage, just to name a few. This discrepancy alone is a major driver of the ~429.6 tCO<sub>2</sub>e/year emissions underestimation observed in the Average Data Method. Additionally, modes like rail and bus, though important nationally, played only marginal roles in the local context, each used by less than **6%** of the survey respondents. This highlights the structural transport inequalities between urban centres and more suburban or rural councils.

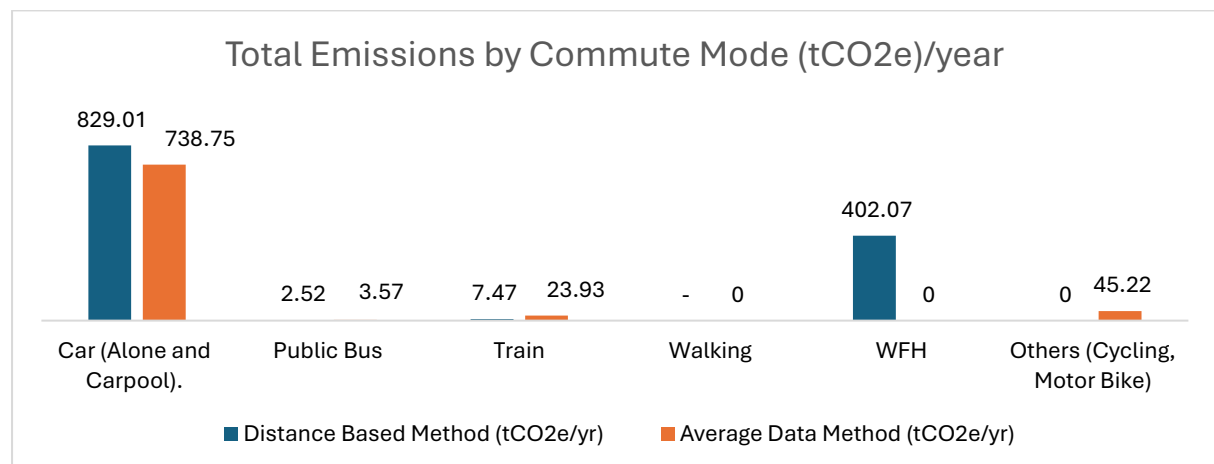


Figure 7: Commute mode Emissions Profile Comparison by method.

Similarly, carpooling accounted for 7% of commuting in the local dataset is not explicitly accounted for in the DEFRA breakdown, possibly being grouped within the general "car" category. However, this difference is critical for emissions accounting: shared car trips significantly reduce per-capita emissions compared to lone car travel, a nuance the Average Data method fails to capture.

Conversely, public transport modes—bus (2%) and train (6%)—are significantly underrepresented locally compared to the national averages of 7% and 10%, respectively. This underutilization aligns with survey themes about barriers to public transport in Middlesbrough—such as poor service routes and unaligned timetables—and further explains the inflated emissions from car usage. Similarly, walking and active transport modes (walking,

cycling, and motorbike) together make up just 6% of local commutes, compared to 17% nationally. This 11% gap again reflects urban design and safety limitations in Middlesbrough, where employees highlighted issues such as unsafe or poorly maintained cycling paths.

Another huge difference in emissions estimate is the home working emissions accounted for by the distanced based method which is totally unaccounted for using the average data method. These comparisons as shown in Figure 8 strongly demonstrate that local commuting realities diverge significantly from national averages, and using the Average Data Method would obscure critical behaviour trends—particularly car dominance and low public transport uptake. For local authorities like Middlesbrough Council, these results validate the superiority of the Distance-Based Method not just in emissions precision, but in guiding targeted sustainable transport interventions.

The emissions comparison between the two accounting methods highlights a significant disparity as shown in Figure 8. The Distance-Based Method estimated 1,241.07 tCO<sub>2</sub>e/year, while the Average Data Method estimated only 811.47 tCO<sub>2</sub>e/year—a difference of 429.6 tCO<sub>2</sub>e/year or approximately 34.6% lower. This variance underscores the limitations of relying on generalised national commuting averages, especially for localised contexts with distinct commuting behaviours.

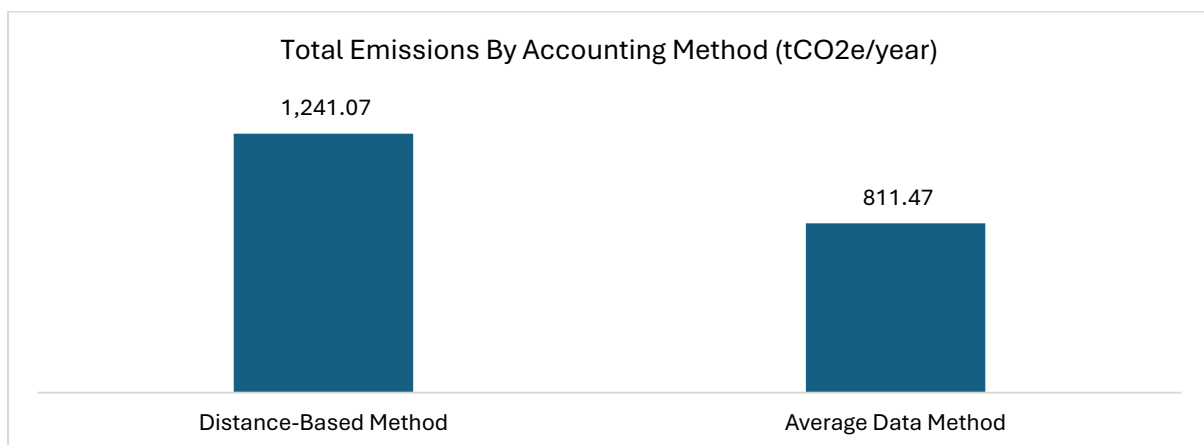


Figure 8: Total Emissions Profile Comparison by method.

This 429.6 tCO<sub>2</sub>e/year underreporting is not just a statistical concern; it reflects a strategic blind spot for local authorities aiming for accurate Scope 3 emissions tracking. Relying on national averages risks misguided policy responses, such as underinvesting in local sustainable transport infrastructure or overestimating the emissions reductions from remote work.

Ultimately, this comparison reinforces the Distance-Based Method as not only more granular but critical for local governments seeking to align with carbon reduction targets and net-zero commitments. As such, it is a preferred methodology where data access and administrative capacity permit.

### 3.7 GLOBAL IMPLICATIONS OF THE RESULT

The findings from this study, while based on a single UK local authority—Middlesbrough Council—have far-reaching implications for global carbon accounting practices, urban sustainability strategies, and climate policy development, particularly in the context of Scope 3 Category 7 emissions. As countries worldwide strive to meet the targets outlined in the Paris Agreement and their respective Nationally Determined Contributions (NDCs), accurate and scalable methods for quantifying indirect emissions such as those from employee commuting are increasingly critical. The comparative analysis of Distance-Based and Average Data methods presented in this study offers several global insights:

Globally, organizations and municipalities face similar challenges to those of Middlesbrough Council: limited resources, data collection difficulties, and the complexity of estimating emissions from diverse commuting patterns. The demonstrated superiority of the Distance-Based Method in capturing granular commuting behaviours—such as vehicle fuel types, hybrid work patterns, and actual distances—highlights its potential as a universal best practice for improving the accuracy of GHG inventories. As more countries adopt mandatory carbon disclosure policies and sustainability frameworks, this method could become a template for local adaptation, especially in urban and suburban settings in both the Global North and South.

The study underscores the importance of empowering local authorities with the tools and knowledge needed to manage their carbon footprints effectively. Given that local governments globally are often the frontline actors in implementing climate policies, the findings stress the value of bottom-up emissions tracking. By integrating robust commuting emissions accounting into local action plans, municipalities in various regions—from European cities to rapidly urbanizing centers in Asia, Africa, and Latin America—can better contribute to national climate goals while improving urban liveability.

Scope 3 emissions remain a blind spot in many international reporting protocols, particularly for service-based and public-sector organizations. This research supports the call for standard-setting bodies such as the GHG Protocol, CDP, and ISO to further refine guidance on employee commuting emissions. It advocates for inclusion of hybrid methodological frameworks that combine Distance-Based precision with the scalability of Average Data approaches. By adopting a flexible yet robust accounting standard, organizations around the world can enhance reporting transparency, improve inter-organizational comparisons, and drive more targeted emissions reductions.

The study's findings on behavioural factors and structural barriers—such as poor public transport and high reliance on private vehicles—resonate globally, especially in contexts marked by socioeconomic disparities and urban sprawl. They emphasize that sustainable mobility is not merely a technological or environmental issue, but one deeply tied to equity, accessibility, and quality of life. Governments, especially in emerging economies, can draw from this study's policy recommendations to design inclusive commuting strategies that prioritize public investment in transit infrastructure, promote modal shift, and address the commuting challenges of vulnerable populations.

Finally, the study illustrates how hybrid work arrangements can significantly reduce commuting emissions, a lesson with universal applicability post-COVID-19. As remote work becomes increasingly normalized across sectors and geographies, its integration into emissions accounting and urban planning offers a viable strategy for organizations worldwide to reduce Scope 3 emissions while enhancing employee wellbeing. The inclusion of homeworking emissions in the Distance-Based method further strengthens the case for its adoption as the global standard and consequently necessary for adoption in national average data method computations as well.

## 4.0 CONCLUSION

This study makes a significant contribution to the evolving discourse on Scope 3 greenhouse gas (GHG) emissions accounting by offering a detailed, comparative analysis of the Distance-Based and Average Data methods for quantifying employee commuting emissions, using Middlesbrough Council as a case study. Amid growing global emphasis on climate accountability and the push toward net-zero emissions, this research addresses a critical methodological gap, particularly within the context of local government operations—a sector often overlooked in emissions literature.

The results clearly indicate that the Distance-Based method provides a more accurate and context-specific estimate of commuting emissions (1,241.07 tCO<sub>2</sub>e/year) compared to the Average Data method (811.47 tCO<sub>2</sub>e/year), with a notable discrepancy of ~429.60 tCO<sub>2</sub>e. This is primarily due to the Distance-Based method's ability to capture individualized commuting variables such as fuel type, engine size, remote working patterns, and actual distance travelled. The research also identified that lone car usage—especially petrol and diesel vehicles—remains the dominant contributor to commuting emissions. Per-capita emissions were higher than the national average, underscoring the need for targeted interventions in car-dependent suburban councils. Behavioural insights revealed that convenience and travel time are the dominant factors influencing commuting choices, with environmental concern ranking significantly lower. However, a large proportion of employees expressed conditional willingness to adopt more sustainable commuting methods if structural, financial, or organisational support were available.

This study is among the first to empirically compare the two primary methods of accounting for Scope 3 Category 7 emissions in a UK local authority context. Its significance lies in its applicability—not only to Middlesbrough Council—but to other municipalities, service-based institutions, and public sector bodies worldwide seeking to refine their carbon accounting practices and inform practical emission reduction strategies. The findings provide a replicable methodological framework and a compelling case for integrating behavioural data, commuting patterns, and hybrid work dynamics into carbon management policies. Despite its contributions, the study is not without limitations. The survey sample, although statistically representative, covered only 100 staff members, which may exclude the diversity of travel patterns among the

broader workforce. Additionally, the study relies on self-reported data, which may introduce recall bias or inaccuracies in travel distances and frequencies. Future research should consider integrating GPS or mobile tracking data to validate survey responses and expand the sample size across multiple councils or regions. Furthermore, the study only partially accounts for homeworking emissions and does not fully explore emissions from business travel or other Scope 3 categories. Expanding the scope to include these variables would enhance the robustness of local authority emissions inventories.

The originality of this study lies in its dual-method comparative approach and its focus on a local government setting—an area typically excluded from advanced emissions research. By combining quantitative emissions data with qualitative behavioural insights, it bridges methodological rigour with human-centred understanding, offering a comprehensive view of how employee commuting impacts organizational carbon footprints. It also proposes actionable strategies for mitigation, tailored specifically to the structural and cultural realities of local councils.

This research demonstrates that the Distance-Based method, while more resource-intensive, is superior in capturing the nuances of employee commuting behaviour and emissions. It presents clear evidence that emissions reduction in public sector organisations is feasible, but requires a strategic blend of improved data collection, sustainable commuting incentives, policy reform, and the integration of hybrid work. Middlesbrough Council—and similar institutions globally—can use these insights to enhance their Scope 3 reporting, promote behavioural change, and move decisively toward their sustainability and climate action targets.

### **Authors Contribution**

Conceptualisation, methodology, formal analysis; Investigation, writing-review and editing- O. A; writing-review and editing, project administration, and Validation- J.U. writing-review and editing, project administration, and Validation, Investigation – E.D.O. All authors have read and agreed to publish this manuscript in your journal.

**Funding** - This research did not receive any funding.

**Data availability**- All data generated or analyzed during this study are included in this article and its supplementary information files will be made available on reasonable request from the corresponding author.

**Ethical approval statement:** Ethical approval for this study was granted by the School of Computing, Engineering and Digital Technologies (SCEDT) Research Ethics Sub-Committee, Teesside University, United Kingdom. The study received research ethics clearance under Review Reference No. 2025 Mar 27750 AJAYI. The research was conducted in accordance with the ethical principles and requirements of the SCEDT Research Ethics Sub-Committee and complied with Teesside University's Six Principles of Research Ethics, including the protection of participants' dignity, rights, confidentiality, voluntary informed consent, and adherence to the highest standards of research integrity and governance.

**Consent for publication** – Not Applicable.

**Consent to Participate**- Informed consent was obtained from all participants involved in the study

**Clinical trial number** -Not applicable.

**Competing interests** - The authors declare no competing interests

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