Modelling transport emission of an out of town centre to achieve emission reduction targets

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Abstract— **Transportation negatively affects the environment due to a high carbon footprint associated with travel. In this paper, we estimate the commuter travel emissions of an out-of-town centre and evaluate the modelled emission against the targets set out by the UK government for 2030 (Climate Change Act), and 2050 (Committee on Climate Change, Kyoto protocol). For the study, primary data is provided by a leading retail centre in the UK in the form of home postcode, and mode selected by its staff for the commute. Each trip's details are extracted using a macro code linking the journey details with google map. An emission model is constructed through the Department for Transport's, Transport Appraisal Guidelines. Modelling for: a) Present mode share, b) Car only, and c) Bus only, with horizon modelling from 2010 -2030. There are 3,444 staff working in the centre, 1743 (51%) use a car and 1701 (49%) bus for the everyday commute. Presently the average emission per person is 3 kg CO_{2e}, modelled to decrease to 2.3 kg CO_{2e} per journey by 2050. It is concluded from the study that a) average emissions for the same trip are expected to decrease, b) the emissions for bus journey are much lower than that of car, c) the targets set out for 2030, and 2050 will not be met if the present travel patterns continue. The modelling has considered advancements in technology, cleaner fuels, and electric vehicles' uptake. The deviation from 2030 and 2050 target is modelled as 29% and 56% respectively. The setout emissions targets are achievable only if a significant change in travel behaviour occurs supplemented by the uptake of sustainable transport modes such as cycling. This study endorses the adverse effects of travel on the environment and makes a case for stronger actions to reduce the travel carbon footprint**

Keywords— transport emissions, travel, UK emission reduction targets.

I. INTRODUCTION

The transport sector contributes to 33% of total emissions, the highest for any UK sector. Although new technologies and incentives are employed to reduce transport emissions and influence travel behaviour the average distance travelled per person has increased significantly [2]. We analyse the effect of an out-of-town retail centre on emissions and model the effect of various incentives for the use of cleaner fuel, better fuel efficiency on emissions and evaluate against the UK targets of emission reduction over to the period to 2050. Whilst such retail centres create jobs and help the economy thrive in the region, they can generate longer trips and have an associated higher carbon footprint [3]. Therefore, a better understanding of the effect on transport emissions of a range of potential interventions is imperative to inform policy and decision making for a sustainable transportation system

Climate change presents a systematic global risk to society threatening essential elements of life, such as access to water, food production, health, land use, and physical and natural capital. Climate change can have significant social consequence, hamper economic growth and increase the risk of large scale and abrupt climatic and ecological system changes. In order to mitigate climate change effects globally, the first international treaty was agreed globally and resulted in the 'Kyoto Protocol 1992' which is linked to the United Nations Framework Convention on Climate Change (UNFCC). This resulted in a commitment to reduce six greenhouse gas emissions (GHG) by 80% by 2050 over 1990 levels [4]. More recently in 2015 the United Nations Climate Change Conference, C.O.P. 21 in Paris, marked a significant step towards climate protection, resulting in an internationally agreed pledge to limit the global temperature rise to 2°C, with a desirable rise of only1.5°C.

The Stern review [5] found that climate change can have severe implications for growth and development. The cost of stabilising the environment are high but manageable, but any delay could be costly and dangerous. A range of options still exist to cut the emissions, but strong and deliberate actions supplemented by policies must motivate their take-up. The review modelled a negative effect of 5% - 20% GDP for any delay in taking action to meet carbon targets. The Eddington Report [6] examined the impact of transport decisions on the UK's economy and environment. It highlighted the need to invest in infrastructure schemes at those locations in the UK network considered congestion pinch-points. In doing so, congested related emissions would substantially reduce. The King review [7] examined vehicle and fuel technologies that could help decarbonise road transport over the subsequent 25 years and concluded that investment was needed to roll out electric and low carbon vehicles.

To ensure the UK meets the Kyoto protocol commitments and reduces emissions significantly for a low carbon economy, legislation was passed by UK parliament in 2008 known as "Climate Change Act (CCA)". This made the UK the first country to establish a long-term legally binding framework to cut emissions, resulting in the Committee on Climate Change (CCC). The target for 2050 has been set up to reduce greenhouse gas emissions by at least 80% by 2050 to 1990 levels. CCA requires the government to set legal binding "Carbon Budget", a cap on the amount of greenhouse gases emitted in the UK over five years, resulting in carbon budgets put in legislation from 2008-2032, with a target of reducing 43% emissions in CO_{2e} from 2015 to 2030. In 2010 the UK Government Policy paper on GHG emissions set out the mandatory target of 67% reduction in carbon emissions by 2050 over 2010 levels [8].

Significant progress has been made from 2009 to 2016 with an improvement in the new cars' efficiency of around 19% [9]. However, there has been an increase in vehicle miles travelled during the same, which has eroded the benefits, and net emissions have not decreased significantly. It is expected that the largest contributor to emission reduction in transport will be achieved through the introduction of electric and low emission vehicles, improved fuel efficiency of new vehicles, better fuels such as biofuels, incentives for the uptake of cleaner vehicles, coupled with higher air quality standards [8].

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The British government's emission reduction targets are explicitly defined in Fig 1, with an aspiration of a linear reduction up to 2050 to achieve the Kyoto protocol target of 80% reduction.

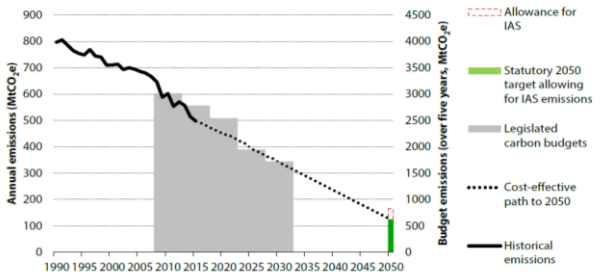

Fig. 1. Target reduction in annual emissions up to 2050 [8]

The study by Allison *et al*. (2016) [9] estimated the carbon emission from the annual energy use for gas, electricity, and transport of 575 households, a representative sample of the Leicester conurbation. This research showed that personal transport emissions make a considerable contribution to the highest third of emitting households. The research also showed that the highest 50% of total carbon emitters were responsible for 96% of transport-related emissions, mainly due to consistently making longer trips both for commuting and out of town shopping.

Therefore, the global aim of this research is to investigate the commuter travel emissions of an out-of-town retail centre and evaluate the emission targets over the period up to 2050. This global aim is achieved through the following objectives:

1. To estimate the emission for the everyday commute trip
2. To model the emissions for business as usual over the period from 2010 to 2050.
3. To test the hypothesis that the emission reduction target set out for 2030 and 2050 will be achieved
4. To estimate the possible deviation from the CCC targets for 2030 and 2050.

II. METHODOLOGY

The study's primary data set is provided by one of the major retail centres in the UK. The data fields included home postcode and travel mode for the staff employed at the retail centre, which has free parking and good transportation connectivity by both bus and rail. The centre houses a major transportation interchange and serves as a terminal bus station for the region with appropriate connectivity to all the major demand centres/residential areas.

The trip distance and time of the everyday commute by each staff member is extracted through Google maps. This is followed by estimating emissions assuming the national fleet for the base case and various scenarios defined by considering different vehicle and fuel types. Finally, the deviation from emission targets is determined.

A. Distance, travel time, and speed

The distance and travel time for each trip is calculated using Google maps for each mode irrespective of the commuter's selected mode. A macro code is written linking the excel worksheet with the origin and destination location, with the Google map to manage the extensive data set provided. The average speed traversed during the trip is determined from the in-vehicle time and distance traversed.

B. Calculating the CO_{2e} emission

The carbon dioxide equivalent (CO_{2e}) is a standard unit for measuring carbon footprints. The different greenhouse gases have different global warming potential. CO_{2e} expresses the impact of different greenhouse gases in terms of CO_2 that would create the same amount of warming, thereby expressing the negative effect of an activity in terms of a single number, allows comparison and evaluation. The CO_{2e} for transport is modelled using the Department for Transport's (Dft) Transport Appraisal Guidance (TAG). CO_{2e} emissions are dependent upon the litres of fuel consumed, and kilowatt-hours (kWh) of electricity used, which are dependent upon the distance travelled and the average speed of the journey. The fuel emission is calculated using by formulae:

$$\mathrm{L} = \frac{\mathrm{a}}{\mathrm{V}} + \mathrm{b} + \mathrm{c} \times \mathrm{V} + \mathrm{d} \times \mathrm{V}^2 \qquad (1)$$

$$\mathrm{L\ per\ commuter} = \frac{\mathrm{L}}{Average\ Occupancy} \qquad (2)$$

where L is consumption in litres per km, V is the average speed in kmph, and $a, b, c\ \&\ d$ are efficiency constants specific to each vehicle types.

These constants are different depending on the year of manufacture and vehicle type and fuel type as the energy source to drive the engine. The percentage of petrol, diesel,

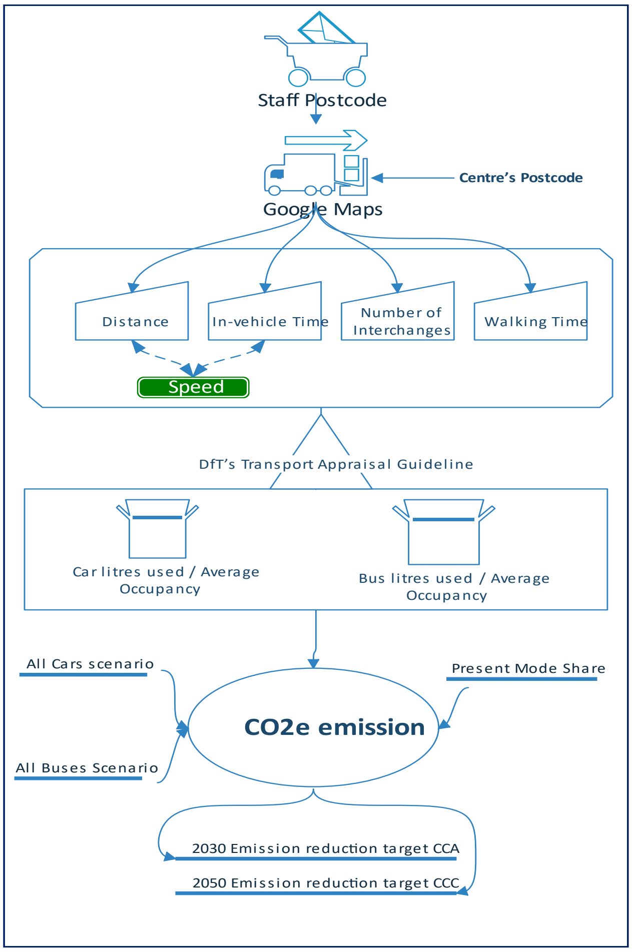

Fig. 2. Methodology used for modelling

and electric cars from 2010-2018 are obtained from section A1.3.9 of Transport Analysis Guidance, TAG workbook [10], whereas the projected share of each vehicle type is given up to the year 2035. TAG assumes the vehicle share to remain constant up to 2050 from 2035. The Public Service Vehicles, PSVs, are all powered by diesel. The values of constants a, b, c and d for all types of vehicles, including their fuel types, were modelled using section A1.3.11 of TAG workbook for years 2010 up to 2089. The equivalent values of the constants a, b, c and d for cars are calculated by multiplying each vehicle type's values by its relative proportion. The litres/kWh per km for each sample is modelled and then multiplied by the distance, thereby resulting in the output of total fuel litres consumed in making the trip. The resultant CO_{2e} emissions are estimated using the emission values using TAG databook section A 3.3.

For each sample, the resultant L for each commuter is estimated by dividing equation 1 by average occupancy. This ensures that the carbon footprint is estimated for the commuter rather than the vehicle. The car's average occupancy is obtained from the National Travel Survey (NTS) as 1.2, and for buses, occupancy study is performed at the retail centre. NTS is a household survey collected through household interviews and trip diaries, the primary source of data on England's travel pattern undertaken by the Department for Transport.

C. *Different Scenario*

In addition to emissions modelling for the present mode share, modelling for different scenarios are also undertaken; if the current bimodal transport trip changed to unimodal a) Car only and b) Bus only. The scenario analysis is undertaken with the assumption that the commuters continue to commute irrespective of the change in the transportation system. Such modelling will enable comparing the present CO_{2e} based on the prevailing mode share (business as usual) with that of the scenarios in which all people shift to either cars or buses completely. The primary motivation is to understand the influence of vehicle and fuel technology and what effect on the emissions of different modes on business as usual and for the future.

D. *Targets*

The targets set up by carbon budgets are calculated, and the reduction that can be achieved through improvement in technology, such as more efficient combustion and engine management systems, cleaner fuels, uptake of electric cars, etc., is modelled and compared. The 2030 target modelling is performed by taking 2015 as a base case (CCA) and a target reduction relative to 2015, assuming a linear target reduction from 2015 to 2030 is evaluated. The target reduction is then assessed with the modelled emission values for different scenarios. The percentage deviation from desirable and that achieved is calculated using equation 3.

$$\text{Percentage Deviation} = \frac{(\text{Achieved} - \text{Desirable})}{\text{Achieved}} \times 100 \qquad (3)$$

The same methodology is applied for modelling the 2050 CCC target analysis, and the calculations are made with 2010 as a base year with a target reduction of 67% by 2050 (CCC).

III. Results and Discussion

Firstly, a bus network system survey is performed to understand the service quality, which is found to be a regular service with a headway of fewer than 15 minutes for all routes. The average bus occupancy on arrival at the retail centre bus station was 12.43 passengers. The service was reliable, with buses departing 96% of the time within 2.5 minutes of the timetable departure time. The bus station is a covered space with adequate seating capacity and free wi-fi, 24-hour CCTV coverage with staffed security. Therefore, we can conclude that the retail centre offers an excellent bus network.

There are 3,444 staff working in the centre, 1743 (51%) use the car, and 1701 (49%) use the bus for the everyday commute. Therefore, the centre already achieves a good proportion of people using the bus, which can be attributed to the bus station's excellent quality. The modelled commuter emission for a one-way trip is modelled from 2010 to 2050, and change in emissions from the previous year given in Table 1. The aggregate everyday staff emissions are 5125 kg CO_{2e} for the one-way commute from their home to the centre, i.e., 1.5 kg CO_{2e} per person for their morning commute, amounting to a daily contribution of 3.0 kg CO_{2e}. This is expected to decrease to 3953 kg CO_{2e} by 2050, i.e. 1.15 kg CO_{2e} per trip and 2.3 kg CO_{2e} per journey for the same modal share.

TABLE I. EMISSION IN CO2E FROM 2010–2050.

Year	Present Conditions	%age change from 2010	%age change from previous year
2010	5286	0	
2011	5241	-1	-1
2012	5254	-1	0
2013	5184	-2	-1
2014	5125	-3	-1
2015	5060	-4	-1
2016	4992	-6	-1
2017	4851	-8	-3
2018	4714	-11	-3
2019	4564	-14	-3
2020	4432	-16	-3
2021	4371	-17	-1
2022	4309	-18	-1
2023	4261	-19	-1
2024	4217	-20	-1
2025	4172	-21	-1
2026	4141	-22	-1
2027	4114	-22	-1
2028	4081	-23	-1
2029	4060	-23	-1
2030	4040	-24	0
2031	4015	-24	-1
2032	4002	-24	0
2033	3990	-25	0
2034	3971	-25	0
2035	3962	-25	0
2036	3961	-25	0
2037	3960	-25	0
2038	3959	-25	0
2039	3958	-25	0
2040	3957	-25	0
2041	3957	-25	0
2042	3956	-25	0
2043	3956	-25	0
2044	3955	-25	0
2045	3955	-25	0
2046	3954	-25	0
2047	3954	-25	0
2048	3953	-25	0
2049	3953	-25	0
2050	3953	-25	0

The results demonstrate that the emissions have decreased from 2010 to 2020 (a 3% decrease every year compared to the preceding years). In contrast, from 2021-2025, the progress reduces by half compared with the progress made each year over preceding years. The gain further decreases slightly from 2026-2035, and the progress almost becomes negligible from 2036-2050.

The initial gain is attributed to the change in the constants used for calculating the fuel burnt per kilometre, especially the value of constant "a". The value of constants is directly proportional to the mileage, i.e., the higher the constants higher is the fuel burnt per mile and vice versa. There is a steady decrease in the constant up to 2020, i.e., improvement in vehicle technology. There is a relatively smaller decrease from 2020 to 2025, as a reduction in the value of the constant of equation 1 starts diminishing significantly afterwards. However, emission reduction during this period is attributed to a steady increase in electric car share up to 2025, after which the rate of growth in electric cars' decreases.

Good progress up to the year 2020 can also be attributed to the reduction in equivalent carbon dioxide emission per litre for petrol and diesel; afterwards, there is no further decrease in CO_{2e} per litre for diesel and petrol whereas there is a continuous reduction in CO_{2e} for electric vehicles. There is a slight decrease in the constant (equation 1) for calculating fuel litres per km from 2026 to 2035. Whatever slight reduction in emissions is achieved from 2035 to 2050 is attributed to the decrease in CO_{2e} emission per kWh for electric vehicles. It is clear that emissions reductions are limited by what is currently expected from vehicle and fuel technologies and whether electric vehicles' anticipated penetration is achieved.

A. Emissions for different scenarios

The emissions for scenarios of a) all cars and b) all bus scenarios are presented in Table II, and Fig 3. It is essential to understand the effect of either a complete transfer to either cars or buses. The results of CO_{2e} for these two scenarios and that of the present mode choice is compared. The different scenario analysis shows that although some progress is expected to be made in the car engine and afterburn technology, there needs to be much more progress made in bus emission. At present, buses are all diesel, and an issue that has emerged is that the fitting of diesel traps to address fine particulates (Euro IV) created elevated nitrogen dioxide, NO_2. This has been addressed by fitting retrofitting NO_2 catalysts, leading to an increase in fuel consumption to exhaust the emissions through the afterburn treatments [11]. Therefore, without Government incentives to introduce low emissions vehicles emissions are expected not to change substantially into the future. The only improvement in these public transport vehicles is expected from reducing the $KgCO_{2e}$ values of diesel per litre, although much research is being invested in introducing hydrogen-fuelled buses [12].

However, the emissions from travel by bus are much lower than cars because they carry many more people and as more people switch to public transport, the emissions per person will fall, and the number of single-occupancy vehicles on the road will reduce congestion with additional carbon savings. Therefore, any change in the mode share towards buses will lead to a less adverse effect on the environment.

TABLE II. EMISSION IN CO_{2E} FOR DIFFERENT SCENARIOS.

Year	Present Conditions	All Bus	All Car
2010	5286	2965	6580
2011	5241	2971	6501
2012	5254	3020	6488
2013	5184	3006	6381
2014	5125	3011	6280
2015	5060	3011	6172
2016	4992	3011	6059
2017	4851	2959	5863
2018	4714	2906	5675
2019	4564	2854	5463
2020	4432	2801	5283
2021	4371	2801	5180
2022	4309	2801	5078
2023	4261	2801	4996
2024	4217	2801	4923
2025	4172	2801	4845
2026	4141	2801	4793
2027	4114	2801	4747
2028	4081	2801	4691
2029	4060	2801	4655
2030	4040	2801	4621
2031	4015	2801	4578
2032	4002	2801	4555
2033	3990	2801	4534
2034	3971	2801	4502
2035	3962	2801	4486
2036	3961	2801	4484
2037	3960	2801	4482
2038	3959	2801	4480
2039	3958	2801	4479
2040	3957	2801	4477
2041	3957	2801	4476
2042	3956	2801	4476
2043	3956	2801	4475
2044	3955	2801	4474
2045	3955	2801	4474
2046	3954	2801	4473
2047	3954	2801	4472
2048	3953	2801	4471
2049	3953	2801	4471
2050	3953	2801	4470

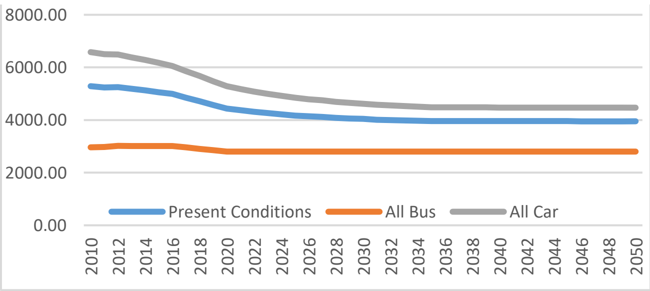

Fig. 3. Emissions in CO_{2e} for different Scenarios of (a) present mode share (b) all car and (c) all bus scenarios

B. 2030 Carbon Budget target

The desirable values to achieve the carbon budget target of 2030 compared to those modelled as achievable with the present mode share are tabulated. The deviation from the target (expressed as a percentage) is given in Table III and Fig 4.

TABLE III. 2030 CARBON BUDGET TARGET.

Year	Achieved	Desired Value	Deviation Percentage
2015	5060	5060	0
2016	4992	4915	2
2017	4851	4770	2
2018	4714	4625	2
2019	4564	4480	2
2020	4432	4335	2
2021	4371	4190	4
2022	4309	4045	6
2023	4261	3900	8
2024	4217	3755	11
2025	4172	3610	13
2026	4141	3465	16
2027	4114	3319	19
2028	4081	3174	22
2029	4060	3029	25
2030	4040	2884	**29**

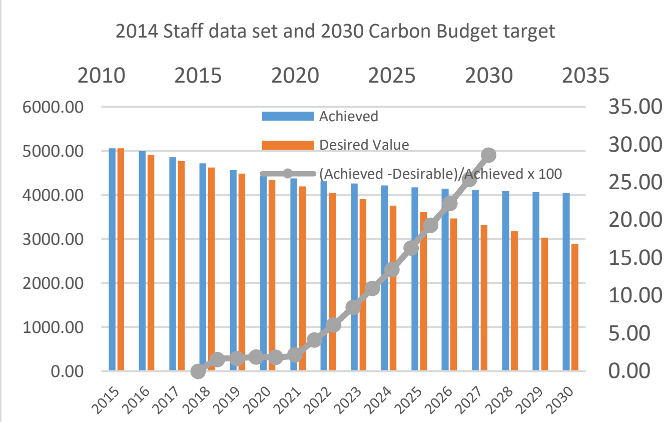

Fig. 4. Achieved desirable emissions and percentage deviation from the 2030 carbon budget target.

The results show that the reduction is never at par with what is desirable for achieving the 2030 target. The difference between the modelled and desirable follows the same pattern as that of reduction in emissions. The difference between the desirable and modelled increases steadily up to 2020, after which it increases exponentially. It is modelled to have a cumulative deficiency of 29% by 2030

C. *2050 Target CCC*

The desirable values to achieve committee on climate change 2050 target and modelled to be achieved with the present mode share are tabulated in Table IV and Fig 5.

TABLE IV. 2014 DATA SET AND 2050 CCC TARGET.

Year	Present Mode Share	Desirable	Deviation Percentage
2010	5286	5286	0
2011	5241	5198	1
2012	5254	5109	3
2013	5184	5021	3
2014	5125	4932	4
2015	5060	4843	4
2016	4992	4755	5
2017	4851	4666	4
2018	4714	4578	3
2019	4564	4489	2
2020	4432	4401	1
2021	4371	4312	1
2022	4309	4224	2
2023	4261	4135	3
2024	4217	4047	4
2025	4172	3958	5
2026	4141	3870	7
2027	4114	3781	8
2028	4081	3692	10
2029	4060	3604	11
2030	4040	3515	13
2031	4015	3427	15
2032	4002	3338	17
2033	3990	3250	19
2034	3971	3161	20
2035	3962	3073	22
2036	3961	2984	25
2037	3960	2896	27
2038	3959	2807	29
2039	3958	2718	31
2040	3957	2630	34
2041	3957	2541	36
2042	3956	2453	38
2043	3956	2364	40
2044	3955	2276	42
2045	3955	2187	45
2046	3954	2099	47
2047	3954	2010	49
2048	3953	1922	51
2049	3953	1833	54
2050	3953	1744	56

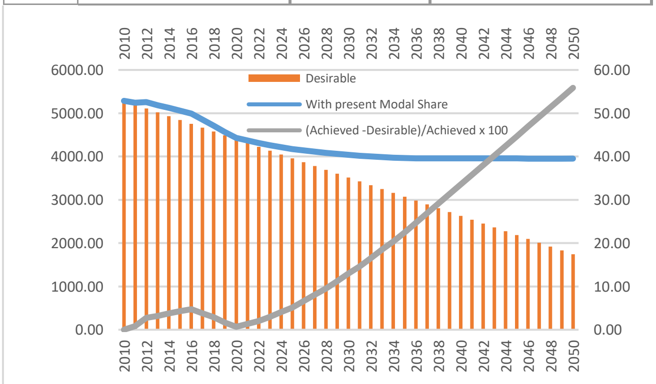

Fig. 5. Achieved desirable value and percentage deviation from 2050 CCC target.

The results indicate that the 2050 emission target will be somewhat in line with the desirable values up to 2022; beyond which, the target deviates from the desired value steadily increasing up to 2027, rises faster up to 2050, resulting in the cumulative percentage deviation of 56%.

Therefore, we can conclude that the Government targets set out for 2030 and 2050 are far from being achieved. The percentage difference in the modelled and desirable values increase significantly from 29% deviation in the 2030 carbon budget target to 56% deviation in the Committee on Climate Change 2050 target. This will have severe implications and many decisive steps need to be taken if the emission reduction targets are to be achieved. Many scenarios need to be modelled so that we can understand how the targets can be achieved. Further work is being carried out on these scenarios, which will be a subject of a further paper.

The modelling presented in this paper has been carried out for the best possible scenarios, i.e., assuming the minimum emission scenario given the following assumptions: a) no increase in the number of vehicles, b) no increase in trips to the retail centre, and c) no increase in congestion. If the targets are not being met with these favourable assumptions, they will certainly not be met in any conditions. Furthermore, it is worthy to note that the UK population is expected to increase from 62.5m in 2010 to 80m by 2050; therefore, radical changes in trip making will be needed in the future.

IV. LIMITATIONS

The targets refer to overall emission reduction throughout the country rather than for a specific emission analysis business. However, these have been assumed to indicate the magnitude of reduction required to inform the decision-makers for a sustainable transport system. Clearly, there is a need for every micro transport demand centre to achieve similar emission reduction; otherwise, the overall emission targets will not be achieved. The targets reduction has to be uniform throughout the country. The emissions estimates are limited by the accuracy of the speeds derived from the distances and travel times from Google maps and the assumption that the passenger occupancy was 12.43, based on the direct measurement of bus arrivals at the retail centre. The modelling scenario of all buses is modelled with the assumption that the buses' occupancy remains the same, i.e., it is assumed that the extra bus trips result in extra buses rather than an increase in the average occupancy. The modelling is performed using the Department for Transport's Transport Appraisal Guidelines (TAG) 2018 guidelines.

V. CONCLUSION

The results of the emission study are based on commuter trips to an out of town centre. The home postcode of all the commuters is used to define the trip origin with the centre's postcode as the destination. A macro code is developed and used to estimate the car and bus travel characteristics of each trip. Using the UK's Department for Transport's Transport Appraisal guide, an emission model is developed to estimate the CO_{2e} for specific scenarios.

Different scenarios are modelled, namely the actual mode share and two-hypothetical scenarios if all the commuters shifted to using a) cars and b) bus. This is followed by comparing the present emissions with the targets set out by the 2030 targets of the climate change act and the 2050 target of 80% reduction mandated by the committee on climate change. The following main conclusions are drawn from the study :

1. The average emissions for the same journey are expected to decrease in the future

2. The bus journey emissions are much lower than car emissions and depend on passenger occupancy. If car travel increases, the emissions are expected to increase significantly

3. The UK government target for 2030 and 2050 will not be met if the present travel patterns continue. The modelling has considered the advancement in technology, cleaner fuels, and forecast for electric vehicles' uptake (15% electric cars by 2035). The deviation from the 2030 and 2050 targets is estimated to be 29% and 56%, respectively.

4. To achieve the emissions targets, a significant change in travel behaviour and the uptake of sustainable transport modes such as cycling is required.

To meet the emission target and save the planet, the prerequisite is to reduce travel costs. This can be achieved by employing staff living in the vicinity, changing the planning structure to reduce the need to travel long distances and incentivising sustainable modes' uptake. The inability to take appropriate action at the right time has resulted in the situation as presented by this research. One possible plan of action can be through carbon tax for centres/ office in which people commute long distance and have a high carbon footprint or incentives in the form of free interest company loans to invest in a home within walking or cycling distance of offices and factories.

Although these measures appear extreme, however inability to act at the right time has pushed the situation this far. Such measures, combined with promoting sustainable modes of travel, such as cycling, shared mobility integrated with public transport, are required. Any delay in action will increase environmental risk, more severe future interventions, and corresponding radical change in travel behaviour required. Earth today is already hotter by 0.89°C, and the COP 21 pathway to a desirable 1.5°C seems a very uphill and increasingly a more unrealisable task. Whilst soft measures could have worked 30 years ago, they are no longer an option. Although electric cars can reduce emission significantly compared to diesel, investment in recharging infrastructure is essential. Furthermore, electric vehicles are not viable without decarbonising the grid, and lithium battery technology alternatives are found [13].

The results from the study present a stark reality regarding transport emissions. Suppose we are to achieve the mandatory target by 2050. In that case, it is essential to change the urban planning policies, change land use patterns to reduce the need to travel not just for employment but for all household activity. Only one intervention, such as the uptake of the electric vehicle or promoting cycling, alone will not deliver but instead a combined integrated approach of a wide range of complementary measures with proper consultations from all key stakeholders is essential to ensure green intelligent transportation system will service essential travel in future. This will be through a combination of uptake of technologies, including cycling schemes, public transport hubs, shared mobility, carpooling, mobility as a service, and land-use changes to reduce the need to travel coupled with radical changes in travel behaviour.

The whole transportation system is expected to change in the near future due to vehicle and infrastructure automation uptake. Therefore, it is imperative to ensure that the environment is at the pivot of any new transportation system. Future research should estimate the emissions reduction of these options and create a prioritised list of the different scenarios' emissions reductions. In turn, this will inform a road map to reach the mandatory 2050 target. However, without full engagement with stakeholders and, more specifically, the public to give them ownership of the future transport systems to deliver behaviour, they are unlikely to meet their potential.

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