2.1.3 Beyond car efficiency and electrification: Examining the role of demand reduction, public transit, and active travel measures to reduce GHG emissions in transport

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Abstract

This paper applies a data set of passenger kilometre transport demand by trip-purpose, mode type and trip-distance based on the outcomes of a National Travel Survey. The Irish Passenger Transport Emissions and Mobility (IPTEM) model enables a system-wide perspective on various measures which could be introduced to reduce passenger transport emissions. Combined with the LEAP Ireland 2050 energy systems simulation model, the carbon abatement potential of trip-purpose based policies, modal shift policies and technology improvements in public transport can be assessed. The results indicate that significant savings can be achieved from modal shift in Ireland, and that trip-purpose based targets and policies have a relevance in the effort to reduce Ireland's energy related transport CO2 emissions. The active mode scenarios, which focus on increased walking and cycling achieve a 0.2 – 1 MTCO2 reduction in annual passenger transport emissions in 2030. The range of public transport scenarios, inspired by targets set out by the Irish Government's Climate Action Plan achieve a between 0.001 – 0.3 MTCO2 reduction in annual passenger transport emissions in 2030. In addition, traffic camera data is used to model the impact of COVID-19 travel restrictions on transport CO2 emissions. The calculated reduction in transport CO2 emissions is 3.9 MTCO2 for 2020 and 2021. This study highlights the importance of factoring modal shift, trip distance and trip purpose into scenario analysis for transport emissions reduction, as it provides a framework for looking beyond only improving technologies in private vehicle transport.

Introduction

To date, solutions for decarbonizing transport have focused on altering the fuel and technology composition of the car fleet. For example, Ireland's most recent Climate Action Plan outlines ambitions to have 845,000 EVs in Ireland by 2030 [1]. Ireland has also committed to an increased biofuel blending rate under the Biofuel Obligation Scheme for vehicles using petrol and diesel [2]. Under the EU Effort Sharing Decision, Ireland has agreed to ambitious targets of 20% emissions reduction below 2005 levels by 2020 and 30% by 2030 [3]. Past national transport emissions reductions policy analyses have focused on private vehicle emissions and the efficacy of an emissions-based vehicle motor tax to encourage a shift in purchases from to cars with a lower carbon intensity [4]–[6]. Other studies have focussed on the role of increased biofuel mixing for internal combustion engines and the role of increasing sales of electric vehicles [7], [8].

The Intergovernmental Panel on Climate Change (IPCC) has noted the rise in global transport greenhouse gas emissions, despite efficiency improvements, as transport activity has increased, while becoming more individual and motorized. The new framing is represented in transport by moves from the low-carbon approach, which focuses on fuel switching, to a comprehensive sustainability approach in the Avoid-Shift-Improve (ASI) framework, as recommended by the IPCC [9]. This approach involves moving through a hierarchy of actions: avoid – avoiding journeys where possible, through innovative spatial planning, compact development and demand management; shift – shifting mode to the more sustainable modes of walking, cycling and public transport; and lastly improve – improving the energy and carbon efficiency of vehicles, including improved designs, choosing smaller vehicles, and switching to alternative powertrains and renewable fuels.

The Irish Government's Department for Transport, Tourism and Sport has also acknowledged that the ASI framework is the best practice approach. Building on this consensus, the next steps required are to ensure that appropriate evidence is made available to inform decision-making at each level in designing policies and understanding measures that can deliver effectively on each level of the Avoid-Shift-Improve framework [10].

Global energy systems optimization modelling identified the possible range of CO2 emissions reductions from modal shift in transport. Cuenot et al. identified a need for national and localized studies to acutely identify the regional scope for emissions reduction through increased active travel and public transport [11]. Transport energy modelling studies up until now for Ireland have focused on the impacts of fuel-switching and the electrification of private vehicles [12]. This study aims to address this need.

Urban based studies of modal shift highlight the possibility for reduced carbon footprint through a switch to active modes [13], [14]. The methods in this paper aim to develop a national projection of how active modes of travel and modal shift can contribute to national efforts to reduce greenhouse gas emissions as pledged under the Paris Agreement.

This study aims to push beyond fuel switching and private car transport to investigate the role of modal shift and demand reduction measures in reducing Ireland's transport CO2 emissions. This model will build on previous knowledge from the technology rich Irish Car Stock Model [15], and the Low Emissions Analysis Platform (LEAP) developed for the transport sector in Ireland [16]. Using information from the National Travel Survey [17], this study compiles a snapshot of mobility and modal choices in Ireland, giving an estimate of the passenger transport demand.

In 2009, the Irish Government published their "Smarter Travel" policy document, which aspired to achieve "10% of all trips for work to be completed by bike". Up until now, it was not possible to monitor the target, and neither was it possible to record the emission reduction implications of achieving such a target. The same document also aspired to have "10% of all journeys completed by bike" and a vision of 450,000 people walking and cycling to work or school each day in 2020, up from 240,000 in 2006" [18].

Comparisons of the abatement potential of technology-, trip- and mode-based measures can be compiled within the framework of the Irish Passenger Transport Emissions and Mobility (IPTEM) Model alongside LEAP Ireland energy systems simulation model. The results will be discussed in the context of Ireland's current transport emissions reduction target to 2030.

Policy areas to be explored in this study include: i) Increased walking and cycling rates and ii) Increased uptake and electrification of public transport.

Methods

The modelling framework used to model increased walking and cycling rates and increased uptake and electrification of public transport involves three elements

1. The Irish Car Stock Model
2. The Irish Passenger Transport Emissions and Mobility (IPTEM) Model
3. The Low Emissions Analysis Platform (LEAP) Ireland Model

An overview of the modelling space is highlighted in Figure 1 (below), followed by detailed descriptions of each of the modelling elements.

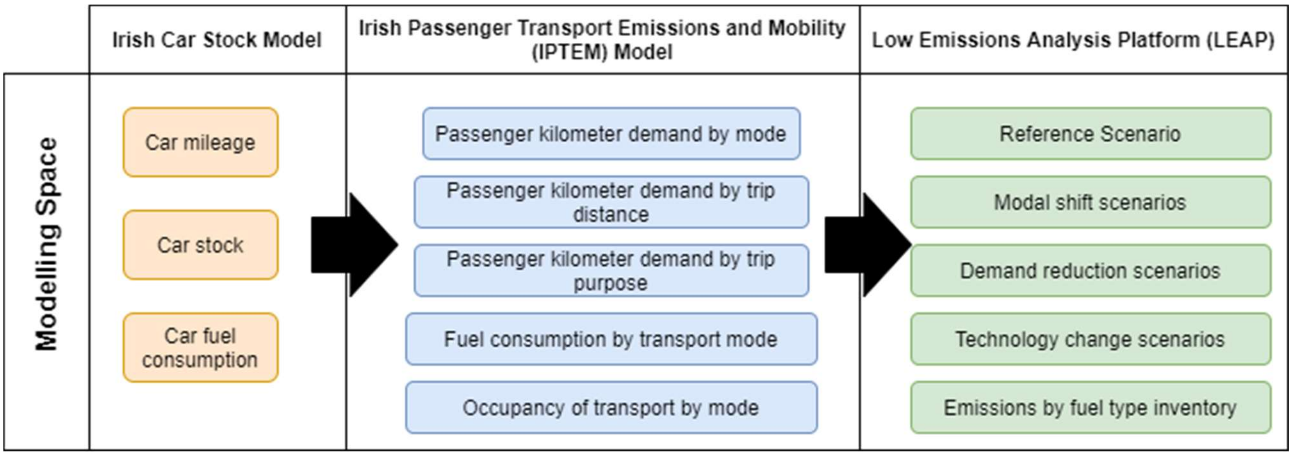

Figure 1: Overview of Transport Emissions Modelling Framework.

Irish Car Stock Model

The first element of the Transport Emissions Modelling Framework builds from a technological stock model of the Irish private car fleet, which was first developed in Daly & Ó Gallachóir, 2011a [16]. The car stock was disaggregated by fuel type, engine cc and age to produce a detailed look at private car activity and energy consumption over the period 2000 - 2018. The car stock simulation program developed for this paper is publicly available on Zenodo [19].

The total number of new private cars from 2000 – 2018 is based on the number of new vehicles registered, as recorded by the Central Statistics Office each year [19]. The car stock model then calculates survival rates of cars and import rates of second-hand cars to develop a picture of the entire car fleet in Ireland.

The Irish Passenger Transport Emissions and Mobility (IPTEM) Model

The Irish Passenger Transport Emissions and Mobility (IPTEM) Model factors in trip-purpose and modal shift in determining passenger transport demand. The IPTEM Model deduces passenger transport demand across all mode types based on responses from the National Travel Survey. By calibrating the passenger kilometres travelled by car with an estimated occupancy rate of 1.5 people and vehicle kilometres as calculated by the Irish Car Stock Model [17]. Combined with the system wide simulation model LEAP (Low Emissions Analysis Platform), these tools can investigate the role of cycling, walking, remote working, and public transport in low carbon passenger transport transitions [20].

Using the IPTEM model, we can observe how modal shift and trip purpose-based transport reductions can influence Irish passenger transport emissions. Passenger numbers, fuel consumption figures and occupancy rates for public transport are based on annual reports from Bus Éireann (nationwide intercity bus service), Dublin Bus (urban bus system operating in Dublin, Ireland), Irish Rail (heavy rail) and Luas (light rail operating in Dublin, Ireland) [21]–[24]. Passenger kilometres travelled in Ireland by mode type, as calculated within the IPTEM model, are shown in Figure 2 (below).

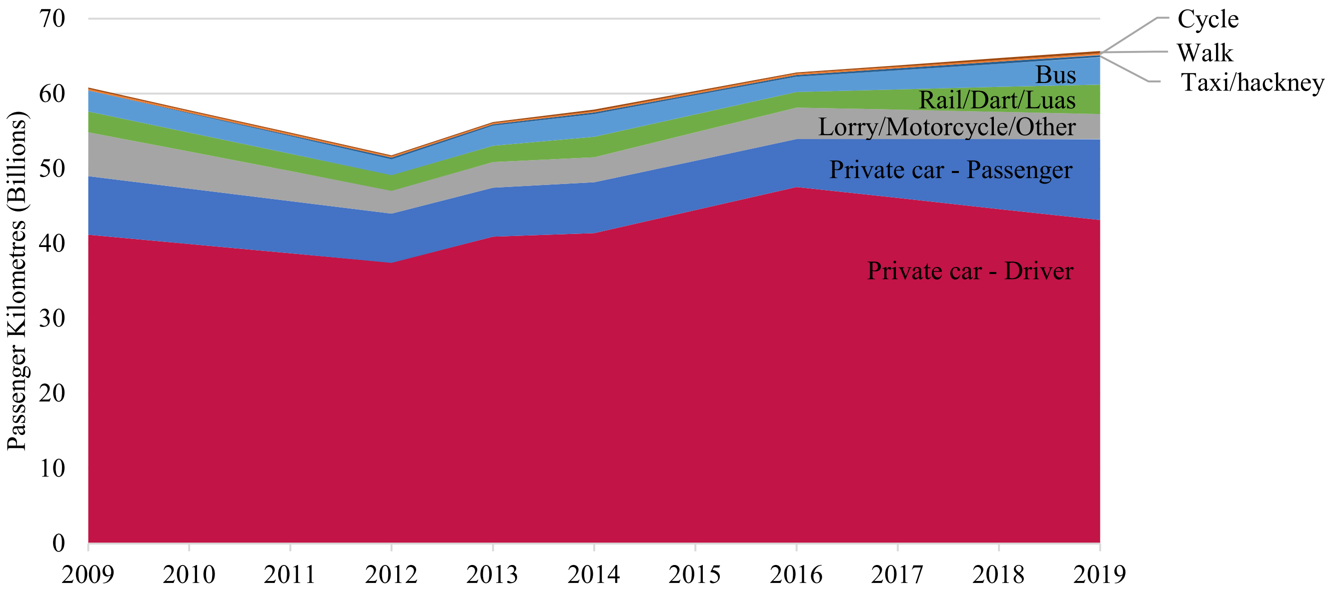

Figure 2: Passenger kilometres by mode type, 2009 - 2019

The energy intensity of each mode type per passenger kilometre (Pkm) was calculated as follows in Equation 1:

$$\text{Energy Intensity}\left(\frac{\text{kWh}}{\text{pkm}}\right) = \frac{Energy\ intensity\ per\ kWh_{f,t} \times Energy\ consumption\ per\ year_{f,t}}{Pkm_t} \quad (1)$$

where *f* is the fuel type, and *t* represents the transit provider (Bus Éireann, Irish Rail, etc.).

The carbon intensity of each mode type per passenger kilometre (Pkm) was then calculated as follows in Equation 2:

$$\text{Carbon Intensity}\left(\frac{\text{gCO2}}{\text{pkm}}\right) = \frac{Carbon\ intensity\ per\ kWh_{f,t} \times Energy\ consumption\ per\ year_{f,t}}{Pkm_t} \quad (2)$$

where *f* is the fuel type, and *t* represents the transit provider.

The carbon intensities of the energy sources are provided by the Sustainable Energy Authority of Ireland [25].

Low Emissions Analysis Platform (LEAP IE 2050)

The third element of the Transport Emissions Modelling Framework uses the LEAP (Low Emissions Analysis Platform) Ireland model. LEAP models use a hierarchical tree structure to define energy demand sectors. These tree structures are flexible and can be designed to incorporate large volumes of granular data. The LEAP transport sector is described by four main subsectors: private transport, freight, fuel tourism and navigation. Private transport further subdivides into distinct subcategories; road private cars, aviation, passenger rail, buses, and active modes of travel (cycling, walking etc.). Private passenger vehicles are defined by vintage (25 years), fuel types (petrol, diesel, electric, compressed natural gas (CNG), hybrid and plug-in hybrid electric), and engine sizes (ranging from less than 900 cc to greater than 2100 cc), based on outputs from the aforementioned Irish Car Stock Model. Passenger kilometres are calibrated against the Irish Passenger Transport Emissions and Mobility (IPTEM) Model.

The platform provides a basis for developing a “business-as-usual” reference scenario, defined by the modeler, and multiple alternate scenarios with variations for comparison. Simulation modelling is particularly useful as it can be easily reused and communicated for custom purposes. Energy consumption rates and net CO2 emissions are handled within the platform by combining stated energy demands with the associated fuel consumption per unit of demand and the carbon intensity of the fuels. Further information on the Low Emissions Analysis Platform is available online [26]. Emissions savings are calculated as CO2 emissions reductions of a stated scenario with respect to the reference, and these emissions savings are highlighted in the results section, as shown in Table 3, Table 4 and Figure 4 (below).

COVID-19 & Passenger Transport Demand

The COVID-19 pandemic resulted in blanket travel restrictions and ‘work-from-home' resolutions in many countries, including Ireland. Transport is one of the main sources of carbon dioxide (CO2) emissions globally. Our paper calculates the impact of travel restrictions on passenger transport demand and the associated CO2 emissions for 2020 and 2021. We apply a novel approach, using road traffic data from traffic cameras nationwide to inform changes in an energy systems model. By comparing traffic volume levels before and during the pandemic, a snapshot of the changed transport mobility patterns was captured. These recorded mobility patterns were quantified in terms of the passenger kilometres by mode type.

At the beginning of the year, traffic counter data indicated a net increase in traffic volumes in 2020, with volumes 9.8% and 7.5% higher than January and February 2019, respectively. On introduction of the COVID-19 travel restrictions on the 12th March 2020 in Ireland, monthly traffic volumes for March 2020 fell 28% below 2019 traffic volumes.

Figure 3 (below) highlights the annual indexed fluctuations in transport demand by vehicle type across the road transport system. Bus and car traffic volumes have experienced the worst effects over the year, with net reductions 26% and 25% below 2019 levels, respectively. Caravans and articulated trucks (HGV_ART) were among the least impacted, with articulated trucks indicating a traffic volume increase of 2.5% when compared to 2019. Rigid heavy goods vehicles (HGV_RIG) and light good vehicles (LGV) traffic volume flows in 2020 were reduced by 11% and 8% respectively.

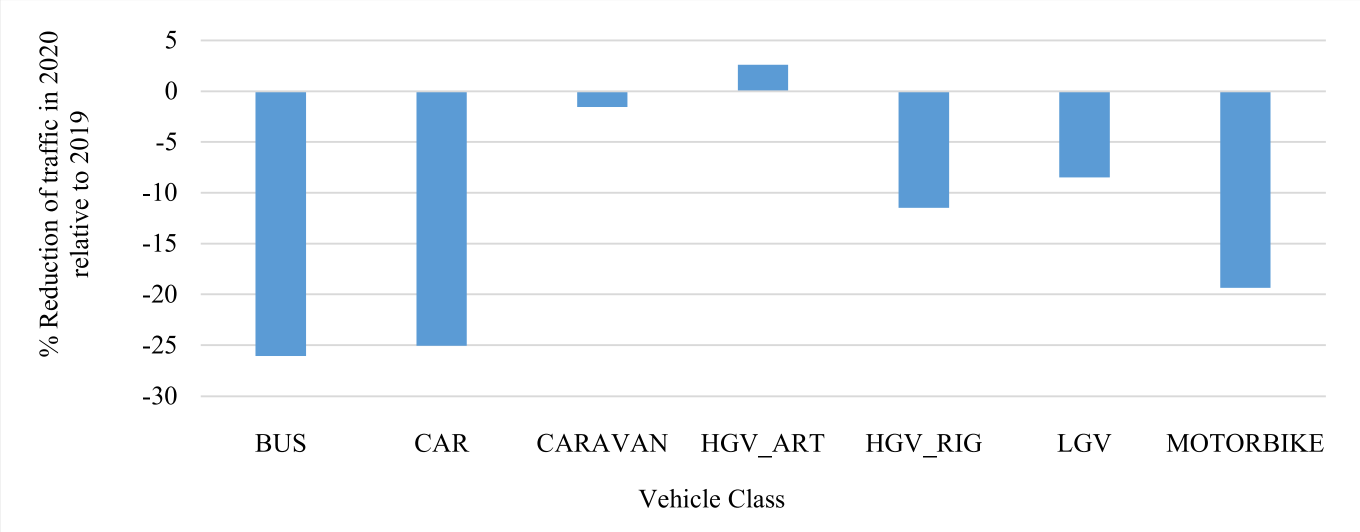

Figure 3: Index of traffic volumes by vehicle class in 2020 (January – November) with respect to 2019

Cycling rates were estimated based on analysing bike counter data from a site on Grove Road in Co. Dublin, which recorded up to a 40% increase in cycling rates, and nation-wide reports of increased bike sale of 30% with a partial regression to pre-COVID levels in 2021 [reference].

Projections for passenger transport demand up to 2030

The Irish car stock is projected using income per adult and car per adult as the drivers. The growth rate of income per adult is taken from the National Transport Model [27]. This income per adult is further used to project the car per adult, using a Gompertz function as shown below (3) [28].

$$y = \alpha e^{-\beta * e^{-\gamma x}} \qquad (3)$$

Where α is the saturation level (maximum number of cars per 1000 persons) is equal to 875; β and γ are estimated. Historical passenger kilometres from CSO's database and car per adult are then used in a regression model to finally project passenger kilometres. For the reference scenario, it is assumed that growth in car passenger kilometres corresponds with an equivalent growth in passenger kilometres of other transport modes.

Active Modes – Walking and Cycling Scenarios

An overview of the scenarios for active modes of travel ran in the LEAP IE model based on inputs from the Irish Passenger Transport Emissions and Mobility (IPTEM) Model is shown in Table 1 (below).

Table 1: Overview of scenarios for walking and cycling.

Scenario	Description
Reference	Assumes no change in share of transport modes from 2019 levels, and demand growth in line with population and economic growth drivers as calculated by Equation 3.
Cycling accounts for 10% of the shortest trips	Share of cycling passenger kilometres increases until it reaches the value of passenger kilometres that represents 10% of the shortest trips
Cycling and walking 450k trips per day	Walking and cycling trips increase proportionally to their current shares until 450k trips per day are either by walking or cycling
Cycling accounts for 10% of work passenger kilometres by 2030	Cycling rate increases for work related travel until 10% of passenger kilometres for work is by cycling
Cycling is 10% of work and education passenger kilometres	Cycling rate increases for work and education related travel until 10% of passenger kilometres for work and education is by cycling
Cycling accounts for 10% of trips of typical cycling journey length	Cycling accounts for 10% of trips of typical cycling length
Cycling accounts for 10% of ALL passenger kilometres	Cycling services 10% of ALL passenger kilometre demand each year.

Public Transport Scenarios

An overview of the scenarios for public transport ran in the LEAP IE model based on inputs from the Irish Passenger Transport Emissions and Mobility (IPTEM) Model is shown in Table 2 (below).

Table 2: Overview of scenarios for Public Transport.

Scenario	Description
Reference	Assumes no change in share of transport modes from 2019 levels, and demand growth in line with population and economic growth drivers as calculated by Equation 3.
Bus Connects	Based on Climate Action Plan Action No. 88 – "Implementation of Bus Connects services network" [1]. This scenario assumes a 20% of car passenger kilometres in Dublin switches to bus, based on studies from past success of mode switching with BRT from studies, which indicate mode shift potential of between 5 - 70% from car to bus following the introduction of a Bus Rapid Transit system [29].
Electrification of Rail	Based on Climate Action Plan No. 93 – Electrification of all railway lines in Ireland by 2030 [1].
Hybrid Rail Fleet	Based on the Climate Action Plan Action No.92 Hybrid fleet for rail, with hybrid fleet, with full hybridization by 2030, and a linear increase from 2023 to 2030. (20% electric, 80% diesel [2])
Extension of Luas line	Based on the Climate Action Plan Action No. 90, "Add additional capacity to Luas network", Addition of Luas in Finglas to Dublin's city center, a 4km Luas line expansion. The scenario assumes that the increase in passenger kilometres will increase. Exploratory scenarios using NTS modality shares for Dublin (using other red & green lines as a guide). Method will increase Luas passenger kilometre proportion, using past usage patterns with respect to line length as a guide for usage patterns with increased rail line length [1].

Results

The passenger transport emissions calculations from the various active modes scenarios as described in Table 1 is highlighted in Figure 4 (below). A summary of results is documented in Table 3 (below).

Active modes of travel

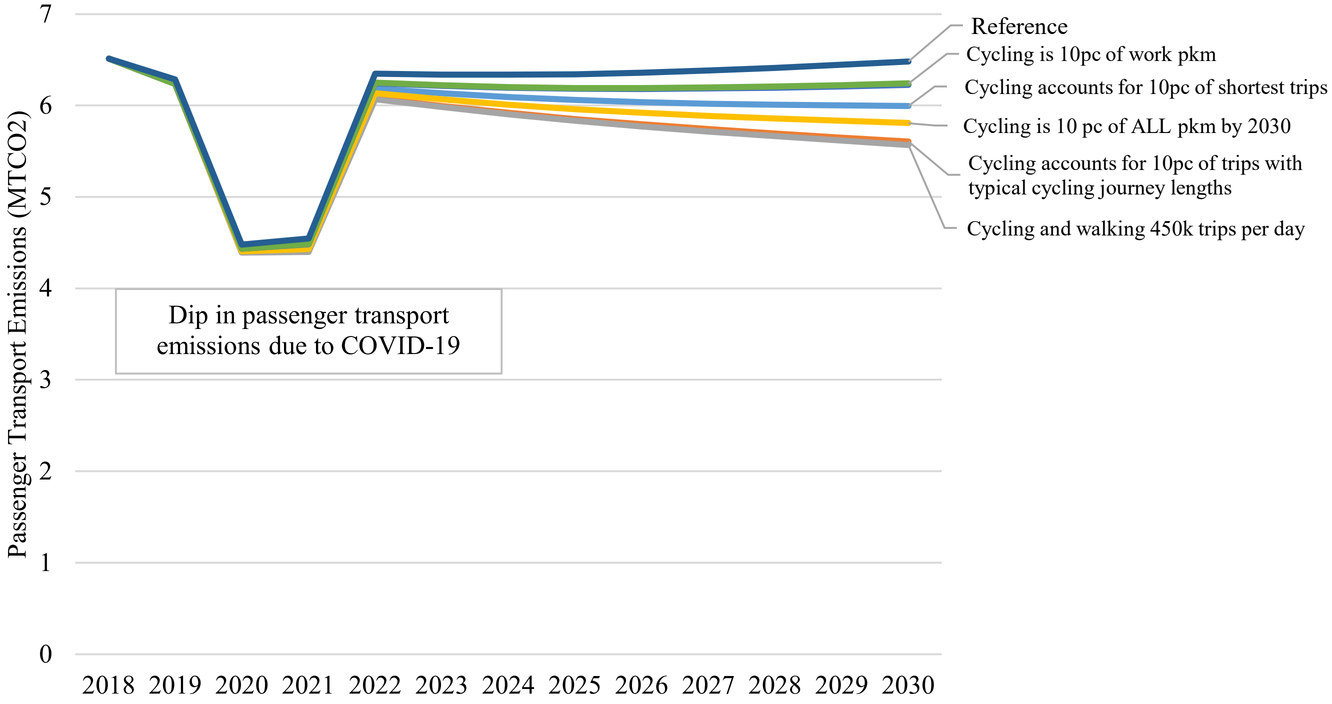

Figure 4: Scenario Comparisons for Energy Related Annual Passenger Transport CO2 Emissions for Ireland (2018 – 2030).

Table 3: Summary of results for Active Travel Scenarios.

Scenario	Annual reduction in emissions by 2030 compared to 2019
	MTCO2
Cycling accounts for 10% of work passenger kilometres by 2030	0.2
Cycling accounts for 10% of work and education passenger kilometres by 2030	0.3
Cycling accounts for 10% of all trips, starting with the shortest	0.5
Cycling is 10% of all passenger kilometres by 2030 (this is the current rate of cycling in the Netherlands [30])	0.7
Cycling accounts for 10% of trips with typical cycling length	0.9
Cycling and walking increases proportional to current penetrations to 450,000 trips per day (Smarter Travel Target [18])	1

Public Transport Scenarios

A summary of results from calculations from the public transport scenarios as described in Table 2 is highlighted in Table 4 (below).

Table 4: Summary of results for Public Transport scenarios.

Scenario	Annual reduction in emissions by 2030 compared to 2019
	MTCO2
Electrification of all rail by 2030	0.3
Hybrid fleet of trains by 2030	0.2
Bus Rapid Transit in Ireland's capital city with "Dublin Bus Connects"	0.04
Extension of the light rail "Luas" (Light rail) line in Ireland's capital, Dublin	0.001

Discussion and Conclusion

The Irish Passenger Transport Emissions and Mobility (IPTEM) model, in conjunction with the simulation based Low Emissions Analysis Platform, LEAP Ireland can demonstrate how demand reduction and modal shift measures can achieve transport emissions reductions in Ireland. The scenarios draw from policies outlined by the Irish Government and illustrate the scale of the challenge to achieve a 7% annual reduction in CO2 emissions from transport in Ireland, and a near 50% reduction in transport related CO2 emissions by 2030. For passenger transport, a 7% annual reduction in CO2 emissions would correspond with a reduction in annual passenger transport of between 3 – 4 MTCO2 by 2030 compared to 2020.

Private car is the most common transport mode in Ireland - many more journeys could be via public transport or via active travel. The active travel policy scenarios highlight the potential of the targets originally outlined in the "Smarter Travel" policy document to achieve tangible CO2 emissions reduction from passenger transport. Our results show that achieving the increased active travel passenger transport targets offers CO2 emissions reductions of between 0.2 – 1 MT CO2 by 2030 from 2019. The public transport measures in the Climate Action Plan (2019) do not achieve a signification reduction in emissions by 2030. Our results indicate that they achieve between 0.001 – 0.3 MTCO2 reduction by 2030 when compared with 2019. Some policies, such as the electrification of all rail, have a far greater impact than other measures, such as the extension of the Luas (light rail) line. The electrification of all rail lines achieves 300 times the CO2 emissions reductions that extending the light-rail Luas does. However, both policies are included as individual actions in the Climate Action Plan, with no prioritization or any indication of their relative impact. Keeping the relative scale of emissions reduction savings in mind is particularly useful when assigning resources to achieving these targets.

Development of the remote working scenarios as noted in the 2020 Irish Program for Government, and future scenario analysis on passenger kilometre demand reduction and modal shift scenarios are areas for future work [31]. Further work should also focus on the interaction effect between different policy measures, as the process of achieving emissions reductions through modal shift may elevate or dampen the impacts of policy measures focusing on another part of the transportation system (e.g. simultaneously increasing the biofuel mixing percentage in fuels and active modes of travel).

In conclusion, this paper has provided a framework for calculating the system-wide emissions impacts of demand reduction from the COVID-19 pandemic and of modal shift policy targets. The framework enables modellers to carry out analysis beyond car efficiency and electrification measures and the study demonstrated to role of public transport, active modes of travel and demand reduction due to the COVID-19 pandemic in transport CO2 emissions reduction.

Acknowledgements

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