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Transitioning to low carbon and sustainable mobility

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Executive summary

This report presents an investigation of existing evidence from academic research and international case studies to assess the suitability of available options and mechanisms to achieve a transition to low-carbon transport in Ireland. The report includes an extensive literature review examining international and national studies that examine innovative methods of reducing emissions from transport. It provides an appraisal of various academic papers, national and international policy documents and other similar projects that have investigated this issue in detail, in addition to examining a number of case studies, which focus on international examples that have successfully achieved marked reductions in carbon emissions from transport.

Overall the report considers mitigation measures under the following headings: Electrification of private car stock, Active Modes, Public Transport and Travel Demand Management Strategies. Following a review of measures under these headings, 14 mitigation options are recommended for Ireland. These mitigation measures are rated in terms of their potential emission savings, the cost of their implementation and the time scale over which they might be expected to have real impacts on decarbonising transport.

Abbreviations

BEV	Battery Electric Vehicle
BRT	Bus Rapid Transit
CAP	Climate Action Plan
CNG	Compressed Natural Gas
CSO	Central Statistics Office
DCCAE	Department of Communications, Climate Action and Environment
DMA	Dublin Metropolitan Area
DPER	Department of Public Expenditure and Reform
DTTAS	Department of Transport, Tourism and Sport
ECF	European Cyclist' Federation
EV	Electric Vehicle
GDA	Greater Dublin Area
GHG	Greenhouse Gas
ICEV	Internal Combustion Engine Vehicle
ITS	Intelligent Transport Systems
LCA	Life-cycle Assessment
LEZ	Low Emissions Zone
MaaS	Mobility as a Service
MM	Mobility Management
NHTS	National Household Travel Survey
NTA	National Transport Authority
OECD	Organisation for Economic Co-operation and Development
PnR	Park and Ride
PHEV	Plug-in Hybrid Electric Vehicle
SEAI	Sustainable Energy Authority of Ireland
TDM	Travel demand management
VRT	Vehicle Registration Tax
WFH	Work from Home

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1. Introduction

In 2016, three out of four journeys outside Dublin were made by car (Department of Transport, Tourism and Sport (DTTAS, 2017) and levels of car dependency tend to be even more exacerbated when there is a need to travel over longer distances within rural areas (Currie, and Senbergs, 2007). However, potential ways of promoting sustainable 'car-shedding' behaviour (Carroll, et al., 2017a, 2017b) in these areas must equally consider the pressing issue of public transport inaccessibility. A key consideration of this document will be a 'just transition' to a low carbon mobility system. In some cases, providing frequent and reliable public transportation to all parts of the country may not be feasible or economically viable. To this end, more traditional modes such as electric cars and on demand shared mobility systems will have to be considered. It is also important to understand what parts of our country fall into this definition and how to focus our resources on ensuring sustainable mobility for all. Benevenuto et al (2020) explored the presence of forced car ownership in Ireland. The research created an index that measures deprivation, access to public transport and car ownership to determine the locations of pockets of forced car ownership. Figure 1 shows that between 2011 and 2016 the numbers of people that fall into the category of forced car ownership in Ireland had reduced, however this is an issue that needs to be considered when examining sustainable mobility.

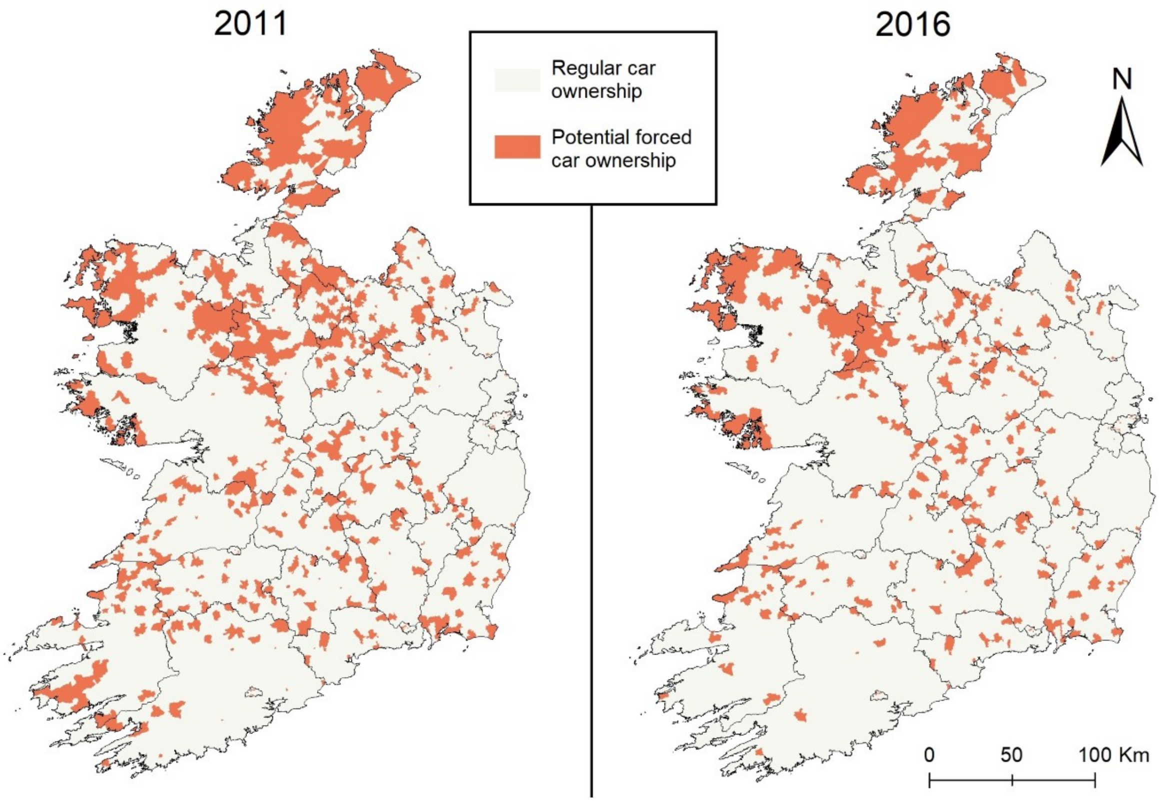

Figure 1 Areas of potential forced car ownership (Benevenuto et al, 2020)

In recent years, Ireland, like many countries globally has experienced a rapid rural to urban demographic shift, which has led to many young and educated people moving to urban areas in regional cities such as Dublin, Cork, Galway, Limerick and Waterford in search of higher paid employment opportunities. As a direct consequence of this, many rural areas have experienced rapid depopulation, with the average age profile in such areas also rising at a similarly accelerated rate. Figure 2 illustrates the extent of this shift in population from rural to urban areas in Ireland based on changes in Census data from 2011 and 2016. Figure 2 reveals that counties in the west of the country, such as Donegal, Sligo, Mayo, and Roscommon have been worst affected by depopulation, while cities in the East and South, namely Dublin, Waterford, and Cork have undergone the highest increases, with exceptions in other regional cities like Galway and Limerick.

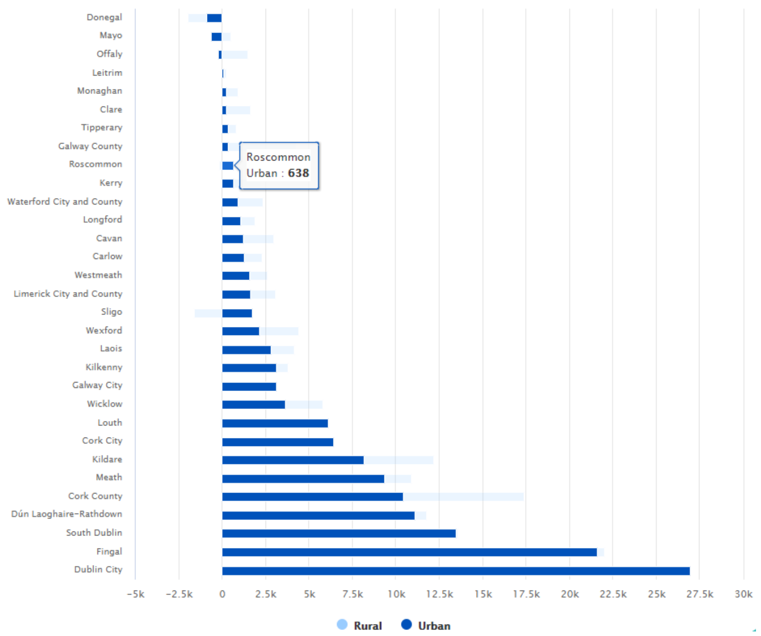

Figure 2 Change of urban and rural population, 2011-2016 (Central Statistics Office, 2016)

Rural depopulation in Ireland has ultimately had a negative impact on transport provision, specifically on the ability of traditional mainstream public transport operators to cater for an increasingly depleted level of travel demand. The consequence of which has led to many transport services needing to reduce their operational frequency or worse, in some cases taking the decision to cease operation outright. Yet, more flexible tailored on-demand services such as LocalLink or vehicle borrowing schemes funded under the Rural Transport Programme, and a focused effort on providing extensive electric vehicle (EV) charging infrastructure to rural communities, have the potential to minimise the incidences and impacts of transport accessibility and poverty in rural areas. Rural transport must also decarbonise, however, in order to do so, an alternative approach to that employed in urban areas is required. However, this ultimately relies on the widespread adoption of EV and the provision of on-demand public transport services.

1.1 Stakeholder engagement

Due to the impact of the global COVID-19 pandemic our team's ability to conduct the stakeholder engagement previously outlined has been limited. However, we have managed to speak to the following listed key stakeholders, and they have been very helpful in providing access to data and models. As the project progresses it is hoped that our team will be able to reach out to more stakeholders to enrich the document produced.

- Climate Change Unit, DTTAS
- The National Transport Authority

- Behavioral Economics Unit, Sustainable Energy Authority of Ireland
- DTTAS, Shannon Office – Motor Tax, Logbooks and change of vehicle ownership
- The Society of the Irish Motor Industry (SIMI)
- Frank Crowley and Justin Doran: Spatial and Regional Economics Research Centre, Department of Economics, Cork University Business School, University College Cork

2. The Challenge of Reducing Emissions in Transport

2.1 The challenge of delivering infrastructure

While Ireland has a strong reputation in delivering roads and highway projects, the same cannot be said for delivering public transport. This can be attributed to a number of reasons. The extended lead time for public transport projects, which necessitate considerable consultation and planning, in particular during route selection, leave these projects at a very high risk of severe delays and potentially cancellation when economic situations worsen. Public transport projects in particular have a history of being subject to more scrutiny than road projects and in some cases have been subject to a higher burden of evaluation and commentary resulting in effective paralysis by analysis. In addition, this long lead time makes it challenging to resume these public transport plans swiftly when economic conditions recover. This inevitably leads to a worsening of the problems which were to have been ameliorated by the new public transport infrastructure, and to a situation where we are constantly trying to play catch up to meet the unmet transport needs of the population. This ultimately has a damaging effect on our competitive ability, leading to even higher levels of congestion, and ensuring continuing unsustainable travel patterns.

The delays caused by stalling a public transport project during difficult financial times leads to declining public transport capacity to meet a growing demand during sustained population growth. The failure to provide adequate public transport infrastructure also inevitably leads to increased car ownership, as frustrated commuters are unable to access good quality, high-capacity, high-frequency public transport. Pausing projects also leads to a decline in the numbers working in construction or with the skills required to develop infrastructure projects, leading to further delays as replacing that skill-set takes time and investment. The most notable examples of this are with the large rail projects in Dublin, MetroLink and DART expansion. It is hoped that the commitment to a 2:1 spending on sustainable transport first recommended by the Citizens Assembly on Climate Change in 2017 and agreed in the 2020 programme for government will start the process of investment in this area (Merrion Street, 2020; Citizens Assembly, 2018).

2.2 The challenge of changing transport behaviour

Breaking habits and encouraging a switch to more sustainable behaviours is one of the greatest challenges with greening our transport system. The cities and regions around the world that we look to for guidance on sustainable transport did not happen overnight. The numbers cycling in Copenhagen today are as a result of sustained societal pressures and levels of investment in this mode that spans back to the 1970's. The sustained investment in infrastructure, education, and promotion of cycling in Copenhagen has resulted in a city today that boasts the highest cycling rates in the world.

The same is true of a shift towards public transport. The cities and countries that we look to with the most efficient public transport systems have had sustained investments in these modes. These public transport systems do not always have expensive rail or light rail networks, bus-based systems have also been shown to provide efficient and sustainable systems.

The main problem that is faced in changing transport behaviours to more sustainable modes of transport is that they have to compete with the private car for investment and road space. The private car, more often than not, can be quicker and much more convenient than using the alternatives. Therefore, to compete, alternative modes need to provide a similar level of service, that is as quick and convenient. However, this comes at a cost. In an economic/ market-based approach to transport policy, development one of the methods to create this shift towards sustainable mobility is called the “carrot and stick” approach. This is whereby a carrot is provided as an incentive, or pull measure, in this case efficient and integrated sustainable transport, followed by a stick or push measure to encourage behaviour change most cases this is some form of road user pricing. This approach has been taken by cities including London, Stockholm, and Singapore to name a few. To get these new networks in place and to change behaviour takes time, political will, and continued investment.

2.3 The high cost of changing our current system and keeping up with demand

The demand for mobility in our cities and across our country is growing as our population grows and our economy expands. In the Greater Dublin Area (GDA), it is predicted that as a direct result of employment and population growth, the number of trips taken in 2035 will be 28.5% higher than that in 2011 (NTA, 2016). The costs of congestion, poor air quality and carbon are growing as our transport networks seek to cater for this growing demand. By 2030, the private car stock in Ireland is predicted to grow above 2.5 million and substantial investment is required in our public transport networks to keep up with the demand.

To meet the demands for the expected growth in trips will be expensive. The planned capital program alone for public transport in Project 2040 is likely to run into billions of euro. It is also expected that investment in public transport alone won't achieve our emissions targets, and that substantial investment will also be required to electrify our private car fleet. However, it should be noted that there will be a significant amount of time needed, like in bringing any of the large public transport projects to fruition, and the same would be true in delivering our EV targets. This is mainly due to the planning and construction time of public transport projects and the expected time required for auto manufacturing to ramp up to the level required across Europe to meet EV targets.

3. A review of transport mitigation options

This section of the document will examine the four main segments of mobility that can contribute to reductions in emissions. Each of these sub-sections examines national and international literature, available data and models, and where possible presents potential costs and emissions savings.

3.1 Electrification of our car stock

In Ireland many studies have been conducted that demonstrate the environmental credentials of a move towards electric mobility (Weldon et al, 2016; Dey et al, 2017). This section of the report does not seek to question the environmental credentials, rather it looks at the feasibility and cost implications of electrifying our private car fleet.

A number of studies have been conducted that examine the potential uptake of electric and alternatively fuelled vehicles in Ireland. Caulfield et al, (2010) conducted one of the first studies on consumer preferences for alternative fuel cars in Ireland. This study used a stated preference approach to determine the impacts of fiscal policies on the car market. The study determined while consumers were concerned about the environmental impacts of driving, cost and safety were still the most important aspects when considering what type of vehicle to purchase. O'Neil et al (2019) conducted an interesting case study on the barriers to the uptake of electric cars, the authors indicate that a lack of a clear policy signal on the future of diesel and petrol vehicles is one of the largest obstacles to electric mobility in Ireland. Mukherjee and Ryan (2020) examined the characteristics of early adopters to EVs in Ireland and found younger and more highly educated urban dwellers were most likely to be within the early adopter group.

One of the key considerations when purchasing an EV is the cost compared to that of an internal combustion engine vehicle (ICEV). Weldon et al, (2018) examines the payback periods of EVs compared to ICEVs, in Ireland, and demonstrates that in order for EVs to be competitive, the current financial subsidies need to be maintained and that usage of these vehicles should be greater than ICEVs in order for a positive payback. This is one of the most interesting findings of this paper, suggesting that those that buy an EV must drive a greater amount than those that own an ICEV in order to have a positive economic payback. In a similar study conducted in Italy, annual distance travelled was also found to be the key variable in determining if EVs are more economically attractive (Scorrano et al, 2020).

3.1.1 Targets of electrification of the fleet

The Climate Action Plan (CAP) published in 2019 contains the government's targets for increasing the number of personal EVs to 2030. The target is that by 2030, 840,000 EVs will be a part of our fleet (DCCAE, 2019). This target will contain a mixture of both battery electric vehicle (BEV) and plug-in hybrid electric vehicle (PHEV) cars. In the CAP, the targets were estimated using McKinsey's Marginal Abatement Cost Curve (MACC) curves. The data and estimates for the increase in EVs were not released as part of the plan, however Figure 3 provides an estimate conducted by the DTTAS on what the likely numbers required are in the ramp up phase towards 2030. The results show that in the initial ramp up phase the majority of electric cars will be PHEV and after 2026 BEV cars are anticipated to overtake PHEVs.

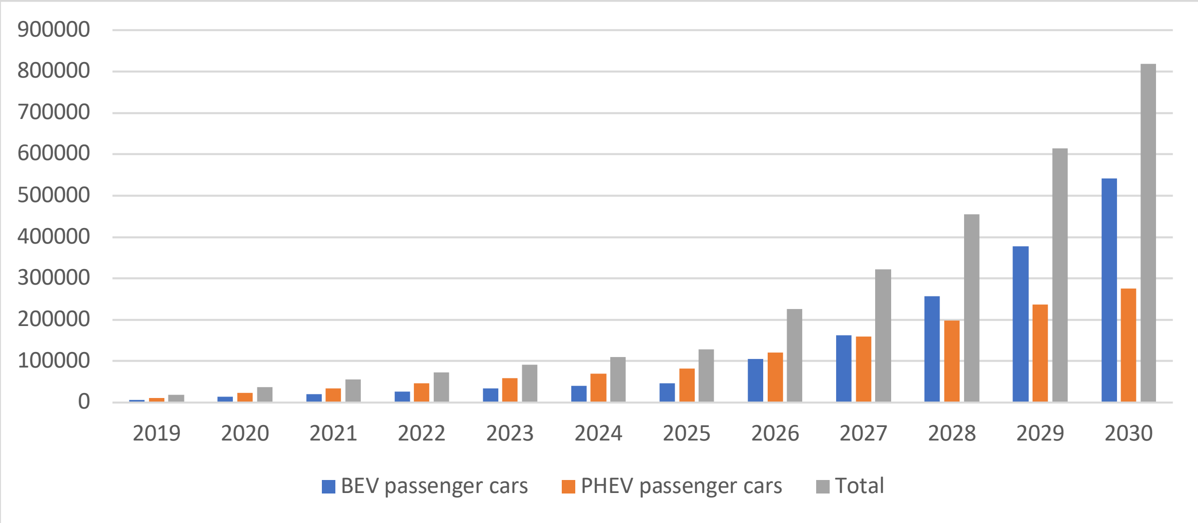

Figure 3 Climate Action Plan Targets for BEV and PHEV vehicles (Source: DTTAS)

The electric mobility targets contained in the CAP are very ambitious. While in recent years the number of EVs being sold in Ireland has increased, the numbers that are required to be sold to reach these targets will require government subvention and or travel demand management tools to encourage this switch to happen. In 2019, 117,109 new vehicles were sold in Ireland, only 4% of these vehicles were electric. This further shows the scale of the distance we have yet to go to meet the target of having 100% of all new vehicles sold to be electric. This target is very ambitious, and it has been commented that these plans are likely to face the challenges of high prices for EVs, lack of availability and choice of models (Herbert, 2020).

By 2030, using a low vehicle population growth scenario, Ireland is expected to have 2.3m private cars, this represents a 30% increase on the 2016 levels (TII, 2019). In 2019, the average age of a vehicle in Ireland was 7.6 years, and cars changed ownership on average 2.4 times during their useful lifetime. It is useful to note that in 2019, a total of 100,000 private cars were scrapped in Ireland, indicating the high/low turnover rate of vehicles in the country.

In 2019, 3,444 BEV and 1,346 PHEV were sold in Ireland (SIMI, 2020), while this is impressive it only equates to meeting 51% of the BEV and 12% of the PHEV targets set in the CAP. In 2020, due to the ongoing pandemic and economic crisis globally, one would imagine reaching our 2020 sales targets will be difficult.

3.1.2 Subsidies and incentives and the cost of transition

The cost to the general public and or to the exchequer of this transition to electric mobility is something that many countries are trying to estimate. In a review of data from 32 European countries spanning from 2010-2017, Münzel et al, (2019) showed that financial incentives had a large impact upon driving the market for EVs. This review has looked at the subsidies that are provided across Europe for the purchase of EVs. The research has shown that most, if not all countries in Europe provide some level of incentive to purchase these vehicles. Norway has the most generous subsidies in Europe and subsequently has the highest rate of EVs per capita. It is not surprising therefore that the research shows that these generous subsidies are the key driver for this high level of market penetration.

Denmark provides an interesting case study on how important these subsidies are in driving the market. In 2015, the Danish government announced a reduction in these subsidies, this subsequently led to a dramatic fall in sales. This policy was reversed in 2017 and has resulted in a large uptake in sales.

Incentivising EVs is expensive and up until July 2019 over €35m in grants had been awarded by SEAI (DPER, 2019). In Ireland, several studies have been done on the economic costs of transitioning to electric mobility. In 2019, Department of Public Expenditure and Reform (DPER) published a review of purchasing personal EVs and showed very low cost-benefit ratios; 0.144:1 for BEVs and 0.097:1 for PHEVs (DPER, 2019). The analysis indicated even at very high carbon tax levels that our current incentives for EVs showed a poor economic return. DPER (2019) estimates that the incentives for BEV are €13,616 and €10,141 for PHEVs. Using these values from DPER and the projections in the CAP, the cost to the exchequer is likely to be €10.4bn. When incentives and tax loss are taken into account, the cost per tonne abated is €1,241 (DCCAE, 2017). It should be that this analysis assumes that the current grants stay in place.

DPER (2019) indicates that the cost of emissions reductions by incentivising EVs places a large cost on the exchequer and that perhaps other mechanisms to reduce greenhouse gases (GHGs) would be more affordable. The paper also suggests that the current incentives may be regressive and favour the wealthy.

A key component of the analysis will be to examine how realistic our targets are to achieve 840,000 personal EV's by 2030. The concerns here relate to EVs and ICEVs reaching parity on cost and how ready the motor industry is to deliver the amount of vehicles required. In an expert study, this issue of the motor industry being ready is flagged as a major concern in decarbonising personal travel at the rates required (de Rubens et al, 2020). Kapustin and Grushevenko (2020) in a global analysis indicate that by 2035 this price parity could be achieved but it may not be until 2040 before EVs make up 11-28% of the global road transport market share. Much of the debate around the future cost of EVs and ICEVs reaching parity revolves around battery prices and reducing or improvements in battery technology. A study published by MIT in 2019 suggests that the current manufacturing cost of an EV is about $10,000 higher than that of an ICEV (MIT, 2019). The same report indicates that this cost differential will persist beyond 2030. The report also indicates that battery costs should decrease by 50% by 2030, this is lower than that reported in the CAP (67%) (DCCAE, 2019).

Outside of academic journals and reports, the commentary on the cost and uptake of EVs is more varied. Some report that the rate in uptake of EVs will be similar to that of smartphones but do recognise that fiscal benefits and access to incentives like carpooling lanes are vital for this uptake (Forbes, 2019). Due to the commercial sensitivity of battery development few reports on the projected changes in cost exist from manufacturers. However, some predict that changing the chemistry of the batteries with a lower reliance on cobalt, increasing energy intensity and therefore decreasing cost could be realised by 2025 (IEA, 2019). Newer manufacturing techniques will assist these novel battery cell chemistries and could see reduced prices by 2024 (BloombergNEF, 2020).

3.1.3 Equity concerns on EV deployment

A key policy making concern is the equitable use of exchequer funds to supplement the cost of purchasing an EV. Over the past decade a lot of focus has been placed upon issues around transport poverty and including equity across society when developing transport policies. This issue is of great importance especially when considering a just transition to a low carbon economy. Internationally, the link between transport equity and climate change transition is poorly understood by policymakers, this is said to be mainly due to a lack of data and policy analysis tools that can include the impacts of equity (Lucas and Pangbourne, 2014). Some industry commentators have indicated that subsidies for the purchase of EVs are ultimately a subsidy for the rich, given that they are primarily only available for the purchase of new vehicles (Ware, 2013; Schwartz, 2011).

With these equity issues in mind, the research conducted for this chapter examined the locations of domestic EV charging points in Ireland. This data was obtained from SEAI and it has the geographic spread of these charging points, which is broken down to the electoral district level. Table 1 also contains the average household income split into quartiles (highest to lowest), and information from the deprivation index which are presented to provide an overview of the electoral districts presented. No statistical relationship between the number of domestic charging points and the affluence and income level has been completed to date (this is planned). However, the results do show that the top 10 electoral districts in Ireland, with the highest number of domestic charging points, are all in the higher income and affluence groups. Further investigation on this dataset will be conducted to determine if any statistical relationships exist.

Table 1 Concentrations of domestic charging points in Ireland (Top 10 areas)

Number of domestic EV chargers by Electoral District	Electoral District	County	Avg household income quartile by Electoral District*	Deprivation Index average score by Electoral District**
66	Lucan-Esker	South Dublin	Highest	Marginally above average
63	Glencullen	Dún Laoghaire-Rathdown	Highest	Affluent
46	St. Mary's (Part Rural)	Co. Meath	Highest	Marginally below average
40	Naas Urban	Co. Kildare	Highest	Marginally above average
38	Navan Rural (Part Urban)	Co. Meath	Second Highest	Marginally below average
38	Douglas	Co. Cork	Highest	Affluent
37	Blanchardstown-Blakestown	Fingal	Highest	Marginally above average
35	Castleknock-Knockmaroon	Fingal	Highest	Affluent
33	Howth	Fingal	Highest	Marginally above average
30	Kilmacanoge (Part Urban)	Co. Wicklow	Second Highest	Marginally above average

*Source: CSO 2016:
https://www.cso.ie/en/releasesandpublications/ep/p-gpii/geographicalprofilesofincomeinireland2016/backgroundandmethodology/
**Source: Pobal Haase Deprivation Index: https://www.pobal.ie/launch-of-2016-pobal-hp-deprivation-index/

3.1.4 Non-financial incentives to purchase EVs

Non-financial incentives tend to focus upon increased charging points, lower parking fees, reductions in tolls/congestion charges and priority access to shared vehicle lanes. Hardman (2019) in a detailed review of non-financial incentives found that their influence depends largely on local conditions such as travel patterns, parking fees and congestion levels. The study suggests that policymaking should vary by region to determine the most suitable policy for that region. This finding is shown in a Dutch study where a policy of free EV parking was shown to be perhaps counterproductive in some cities as people charged their cars for longer in these spaces resulting in an inefficient use of charging infrastructure (Wolbertus et al, 2018). A Norwegian study examined non-financial incentives comparing bus lane access and increased charging stations, the results for personal consumers showed bus lane access was less attractive as they previewed these lanes to be congested and preferred a denser network of charging points (Zhang et al, 2016).

In more recent years, there is a growing body of literature that examines policies that would make the purchase of an ICEV less attractive. Letmathe and Suares (2020) examined the concept of perceived risk of purchasing an EV compared to an ICEV in Germany. The study found that the risk of ICEV's being banned from driving in some cities and the introduction of information and awareness campaigns on the total cost of EV ownership had strong influences on purchasing decisions. As greater uncertainty about the use of ICEVs grows in the form of low emission zones and carbon taxes, this could result in a switch in preferences towards EVs but more research is needed in this area.

3.1.5 Key findings - Electrification of our car stock

- In Ireland the tools we used to assess the take up of EVs mainly show the potential emission savings, none of these models include any Irish behavioural data, and therefore we don't know how Irish consumers may react to changes in incentives or curtailments on using petrol and diesel vehicles.
- Research is needed to determine the impacts on Irish consumer behaviour on the impacts of financial incentives, disincentives to purchasing ICEVs (low emission zones etc), equity impacts of these grants, and the return on investment compared to incentivising other low carbon modes.
- The cost to the exchequer of following the targets set out in the CAP for personal EVs is very high.
- The cost benefit analysis ratios produced by DPER show a very low return on investment – while it should be noted this analysis assumes full subsidies continue to 2030.
- The academic and industrial literature on the cost of EVs and batteries seems to indicate that the cost differentials are unlikely to reach parity before 2030 whereas some of the industry commentary indicates this could happen faster.
- When examining the cost to the consumer, several studies have shown that in order for EVs to be competitive, owners must drive these vehicles a lot more to get the same economic return.
- The literature argues about the equitable nature of its subsidising the purchase of EVs, some indicating that this is a tax break for the wealthy.

3.2 Active modes

3.2.1 Context of Active Modes Use in Ireland

Pedestrians and cyclists are the most exposed road users and suffer to a greater extent from poor air pollution than any other mode of transport. They also exert the lowest environmental impact and coincidentally are the most freely available and accessible modes. However, levels of cycling nationally in Ireland have oscillated significantly in the past three decades as more people have developed lifestyles, habits and routines centred primarily around car-use, which has ultimately led to an overreliance on the private car to facilitate many daily activities.

On a regional level, Table 2 displays the walking, cycling and overall active mode shares for work and education trips in each of the five regional cities from the 1996 to 2016 Census results. The data presented in Table 2 demonstrate that the levels of walking and cycling across the country decreased significantly during this period. From 1996-2006, each of the regional cities experienced a reduction in the numbers of commuters using active modes, before increasing in 2011 and 2016 in some cities (i.e. cycling in Dublin and Galway). The fall in cycling mode share in Galway and Limerick was most dramatic as 3.22% and 2.27% reductions were recorded respectively. Dublin recorded a significant increase in the number of cycling trips between 2006 and 2016 (2.45%). It has been widely reported that there has been a growth in cycling in Dublin, as the city has experienced a resurgence in cycling in line with an increase in investment in cycling facilities during this period (Caulfield, 2014). This has been evidenced by Dublin cordon counts which have shown that the share of cycling as a mode has grown by 60% between 2006 and 2016 (Carroll et al., 2017a; DCC, 2016). This census data also shows that Dublin, closely followed by Limerick, have consistently had the highest pedestrian mode shares amongst the five regional cities. It must also be noted that the data presented is in reference to commutes to work, school and college trips and does not include other trip purposes (e.g. recreational).

Table 2 Cycling and Walking Regional City Mode Shares for trips to work (1996-2016)

	Cycling Mode Shares (%)				
	1996	**2002**	**2006**	**2011**	**2016**
Dublin	6.07	4.21	3.86	4.90	6.31
Cork	2.61	1.10	0.95	1.08	1.26
Limerick	3.76	1.83	1.49	1.32	1.51
Galway	5.29	2.12	2.07	2.06	2.28
Waterford	3.99	1.84	1.31	1.22	1.38
	Walking Mode Shares (%)				
Dublin	23.28	21.01	20.07	20.15	19.02
Cork	20.40	16.70	15.16	14.05	12.93
Limerick	22.37	19.16	17.08	14.96	14.08
Galway	17.43	15.34	14.05	12.10	11.50
Waterford	17.73	18.11	15.67	14.27	13.40
	Mode share of Active Modes (%)				
Dublin	29.35	25.22	23.93	25.05	25.33
Cork	23.01	17.80	16.11	15.13	14.19
Limerick	26.13	20.99	18.57	16.28	15.59
Galway	22.72	17.46	16.12	14.16	13.78
Waterford	21.72	19.95	16.98	15.49	14.78

The mode share of a city or country is influenced by the interrelationship of many interrelated factors such as population and density, geographical size, levels of car ownership (i.e. number of cars owned or available per household), household income, number of dependents, weather conditions, distance, gradient, and land zoning (Santos et al., 2013). A recent study by Lades et al. (2020), which was conducted using campus travel survey data from University College Dublin, determined that variations in travel behaviour and trip satisfaction can be attributed to the length and trip time associated with certain modes. As such, these factors are significant mode choice characteristics in Dublin for commutes to universities. For example, walking and cycling may be viewed as being more time efficient modes to take during peak hours of the day, when bus services may suffer delays due to high levels of traffic congestion. It is also noteworthy that mode shares are a reflection of a series of interrelated elements and not one single feature or attribute, hence encouraging a reduction in the mode share of private cars by simply investing in walking and cycling is not sufficient as private car use is often dictated by land use characteristics (i.e. the physical separation of the activities in residential and employment areas) and the convenience associated with this mode.

In a recent study conducted by the NTA and Sustrans (2020) it was determined that in the Dublin metropolitan area (DMA) cycling saves approximately 28kt of GHG (carbon dioxide, methane and nitrous oxide) emissions. In a survey conducted as part of this study it was found that 75% of the respondents would like to see more government spending on cycling, 71% on public transport, 61% on walking, while 34% of the sample would like to see more spending being devoted to car related infrastructure (NTA and Sustrans, 2020). In 2019, 70.5 million cycling trips were recorded in the DMA, with 60,000 return trips taking place daily. Perhaps the most surprising finding from this study was that 84% of people living in the DMA would be in favour of the government investing in segregated cycling infrastructure at the price of road space for other modes of transport (NTA and Sustrans, 2020). In other words, the vast majority of the sample were in favour of allocating road space to facilitate safer cycling. Furthermore, 58% of the sample stated that they would support charging polluting vehicles more to enter Dublin city centre.

Moreover, a study conducted by Caulfield et al. (2012) found that the provision of fully segregated cycle lanes in Dublin resulted in 74% of a sample of respondents altering their perception of the safety of cycling, with 56% stating that they would consider an up take of cycling if such facilities were in place.

Research conducted by the European Cyclists' Federation (ECF) (2011) estimated that a combination of 'avoid and shift measures', that is a combination of planning, regulatory, economic, information, and technological instruments, could allow for a 21% reduction in GHGs from a base 'do nothing' scenario by 2050. While a combination of 'improve, avoid and shift measures' could achieve an 84% GHG reduction. This is in keeping with a study by Carroll et al. (2020) that examined the effectiveness (or ineffectiveness) of offering incentives alone as a means to stimulate a shift from single occupancy vehicles to sustainable modes for commuter trips in the GDA. The results of which show that incentives on their own, that is when not teamed with a disincentive to drive, are not sufficient to encourage a significant reduction in private car trips. Rather they encourage shifting behaviour between sustainable modes, for example from public transport to walking and cycling) In this study, a range of mode-specific policy incentives tested were found to lead to a reduction in the mode share of private cars of up to 1.6%, while there was a 5% increase in the mode share of walking (Carroll et al., 2020). As a result of such a mode shift, up to 303 tonnes of CO_2 emissions were estimated to be saved daily. Hence, while active modes may commonly be viewed as only suitable for short distance trips that is those between four and six kilometres, walking and cycling are nevertheless viable alternatives for some private car trips and as such can reduce CO_{2e} emissions (Goodman, et al., 2012; de Nazelle, et al., 2010; Ogilvie, et al., 2004; Saelensminde, 2004).

However, in the context of climate policy, specifically carbon emission reduction and climate change mitigation, the support for increased investment in walking and cycling when teamed with information provision and active mode promotion is apparent in the literature as a sound investment, which gives greater returns than many alternatives, attracting a shift away from private vehicles (Brand, Goodman and Ogilvie, 2014). For example, Transport for London's 'Walking and Cycling Economic Benefits summary pack' states that the economy receives £13 of benefits for every £1 invested in walking and cycling (TfL, 2018).

Table 3 outlines the series of active mode targets and objectives set out in various national reports and strategic documentation in the past two decades. Many of these targets of course overlap with each other, however current national active modes targets and objectives in Ireland rely on the successful design, implementation and investment of large public transport projects such as BusConnects, in order to deliver improvements in walking and cycling infrastructure. Projects such as BusConnects are welcome improvements to transport infrastructure in Ireland, however in reality the 200km of segregated cycle lanes proposed will not be sufficient to deliver the cycling network needed in regional cities such as Dublin and Cork to facilitate the increasing numbers of people cycling in these cities. It must also be noted that there will also likely be a lengthy lead-in time associated with such projects as an extensive consultation process is involved.

Several of the actions presented in Table 3 similarly focus on broad statements in relation to the development of an implementation strategy for a cycling network. However, the 2013 GDA cycle network plan, which consists of 2,840km of cycle lanes connected with minimal gaps in the 'network', has yet to be implemented in its entirety at the time of publication (2020). In conjunction with the newly established NTA Cycling Office, the creation of a similar office in the DTTAS would be welcomed in order to help coordinate and support the implementation of various cycling projects nationally and ensure that sufficient funding is provided to see these projects finalised.

Walking is often discounted as an appropriate transport mode, however according to the transport hierarchy, pedestrians are placed at the top and as such should be prioritised over other transport modes, however arguably transport policy in Ireland has historically not necessarily reflected that concept. A number of wide-ranging statements have been made promising 'traffic free urban centres', 'improving the surface quality of footpaths', etc., however much of these pledges are simply 'tick box' assertions, which ultimately do not usually transpire, suggesting that the consideration of pedestrians, particularly in inner urban areas are not taken seriously. The International Transport Forum (2018) state that 'urban planning activities should prioritise density, connectivity and destinations when seeking to increase pedestrian opportunities' and that improving walkability can only be achieved by strategically planning the urban pedestrian network by considering accessibility to key trip attractors (employment, retail, recreation) and how they link up with the location of key trip generators (residential). Research conducted by Carroll et al. (2019) has shown that policy incentives that promote walking and enhance the public realm for pedestrians, are more effective in achieving a positive mode shift than any other comparable mode-specific incentives offers to alternative modes in the GDA.

Table 3 Actions, Targets and Objectives from National Reports and Strategic Publications

Policy/ Reports	Actions/ Targets/ Objectives			
Climate Action Plan (2019)	Establish a cycling project office with the NTA, publish a 5-year strategy	Develop overall cycling implementation plan across region cities	Timeline to seek planning consents and commence construction for initial cycling projects	Commence full implementation of the National Cycle Policy Framework
National Development Plan (2018)	Delivery of comprehensive cycling and walking network for Ireland's cities and expanded Greenways	200kms of cycle facilities as part of BusConnects	Approximately €365 million (2018 to 2022) available to support cycling and walking and sustainable urban transport programmes.	Funding is also available under both the Urban and Rural Regeneration and Development Funds
National Planning Framework (2018)	Ensure the integration of safe and convenient alternatives to the car into the design of our communities, by prioritising walking and cycling accessibility to both existing and proposed developments and integrating physical activity facilities for all ages.	Enabling more effective traffic management within and around cities and re-allocation of inner-city road-space in favour of bus-based public transport services and walking/cycling facilities	Develop a comprehensive network of safe cycling routes in metropolitan areas to address travel needs and to provide similar facilities in towns and villages where appropriate	
National Cycle Policy Framework (NCPF) (2009)	Creation of traffic-free urban centres to facilitate cycling	Investment in a national cycle network with urban networks prioritised	Cycle training for school children	Integration of cycling with other modes e.g. carriage of bicycles on public transport
Smarter Travel (2009)	- Providing safe pedestrian routes - Publication of a national walking policy - Improving the quality of footpaths	- Integration of cycling and public transport - Cycling will be encouraged as a mode for other purposes so that by 2020 10% of all our trips will be by bike	- Introducing 30km/h zones in central urban areas - Develop national policies for cycling and walking and oversee their implementation	- Car drivers will be accommodated on other modes such as walking, cycling, public transport and car sharing (to the extent that commuting by these modes will rise to 55% by 2020) or through other measures such as e-working

Figure 4 illustrates the CO_2 emissions (tonnes) produced from transportation per inhabitant by various Organisation for Economic Co-operation and Development (OECD) countries from 2000 and 2014. The data shows that transport in Ireland produced a high of 3.3 tonnes of CO_2 per inhabitant in 2007 versus a low of 2.3 tonnes in 2011-2013. In 2014 2.4 tonnes of CO_2 was recorded in Ireland, which placed Ireland above many European OECD countries such as Germany, Denmark, The Netherlands, the United Kingdom, Spain, and France. Research conducted has estimated that if the EU cycling mode share in 2020 equalled the levels experienced in Denmark in 2000, up to 120 million tonnes of CO_2 equivalent would be saved annually, which represents more than 57% of the EU GHG transport target for 2020 (ECF, 2011).

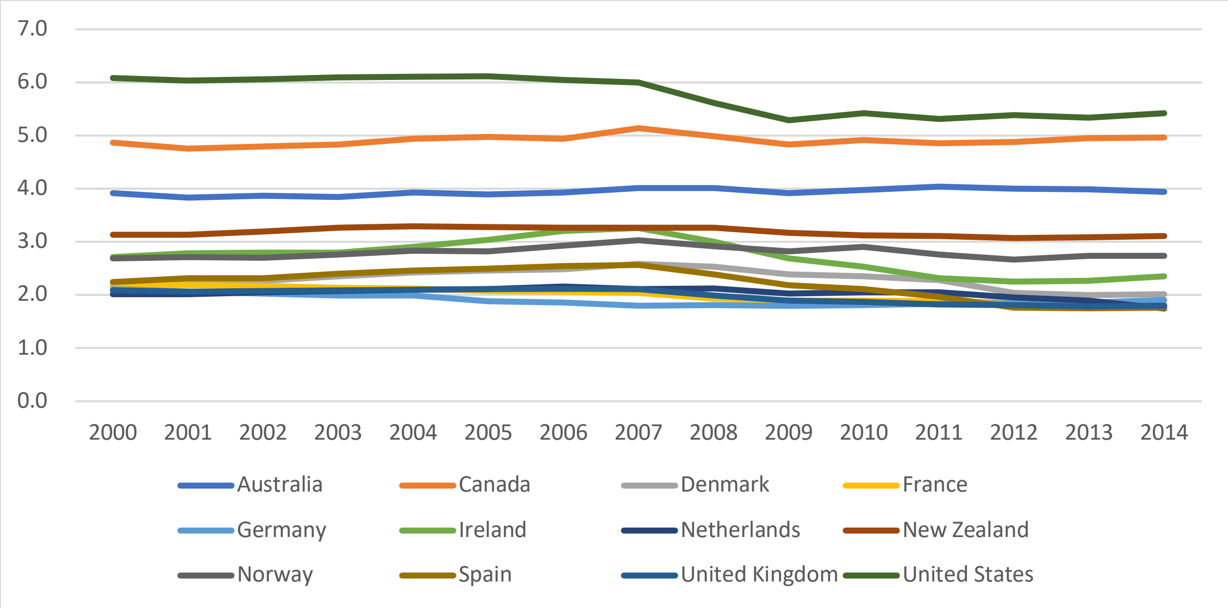

Figure 4 CO2 emissions from transport in tonnes per inhabitant 2000 - 2014 (OECD, 2020)

3.2.2. Literature and Case Study Review

In the past decade the academic research community has witnessed an increase in the popularity of cycling in many European and American cities. This shift in empirical attention has been represented by a surge in cycling research being produced in academia, with an average increase in academic publications from 197 annually in the period of 1991-1995 to 610 per year in 2011-2016 (European Cyclists' Federation, 2017; Pucher and Buehler, 2017). However, the academic literature to date that concerns the topic of active modes, focuses principally on the health benefits that walking and cycling as modes of transport offer to users, rather than any potential CO_2 emissions. As a result, there are relatively few studies that report empirical emissions savings from the uptake of active modes alone. Neves and Brand (2019) affirm that in stating that there is a deficiency in empirical evidence which considers the potential of active modes to encourage a mode shift from private cars and the potential GHG emission savings. In this way, the opportunity for walking and cycling to achieve CO_2 emission reductions from reducing the number of motorised trips has 'received little attention', as studies have focused on determining the mitigation of emissions indirectly (Yang, et al., 2018; Tainio, et al., 2017; Brand, et al., 2014; Lovelace, et al., 2011). Mizdrak et al. (2019) created a unit-level questionnaire to estimate the potential of active transport to reduce GHGs, improve health and as a result reduce healthcare costs in New Zealand. In this study a number of scenarios were modelled to estimate changes in kilometres travelled by different modes and the changes in emissions. Scenario A examined shifting 25%, 50% and 100% of car trips under one kilometre to walking; while Scenario B modelled the same percentages of car trips under five kilometres shifting to walking and cycling. The results from this study found that CO_2 emissions were reduced by 5.6 kilotons (kt) of CO_2 equivalent per year based on a 25% mode shift scenario and up to 436ktCO_2e/year from 100% mode shift scenario, which would correspond to 4% of all road transport related emissions in New Zealand (Mizrak, et al., 2019).

Case Study 1: BiTiBi and integration/ combination of cycling and rail

BiTiBi (an abbreviation of bike-train-bike combination) was a European research project and pilot that tested a range of measures and incentives to greater integrate rail services with cycling and make the combination more attractive to potential travellers. This project ultimately promoted the integration of the most energy-efficient transport modes with the bicycle, in order to make the combination a more competitive option versus the private car, with the bike being ideal for short distances and the train for longer distances. The precise location was based on analyzing and understanding steps taken in the Netherlands to successfully integrate these modes seamlessly and replicate it in other selected cities in Europe. Central to the success of this concept in the Netherlands has been attributed to the popularity of the OV-Fiets share bike service, which allows users to pick up the bike at the station, go to their final destination, for example their home and return to station the next day with the same bike. This service is provided by the main railway operator in the Netherlands; thus, it is in their interest to make it easier and more convenient for their patrons to access the train station from their home. The pilot was conducted in 5 European countries (Belgium, the Netherlands, Italy, England, and Spain), where a range of instruments were introduced to tackle the existing barriers to using the service. Some of the measures implemented included:

- Bike routes to train stations provided with involvement of local authorities
- Provision of a specific type of convenient shared bicycle – tariffs allow bikes to be kept for 24 hours without penalty.
- Sheltered and secure bike parking and shared bicycles are signposted, information provision
- One integrated tariff and payment system, i.e. one card/app enables payment of all services (e.g. Dublin bikes and Leap card integration) (EEA. 2019; ECF, 2011)

For the Belgian pilot, in the city of Ghent, the results showed that 22% of shared bike users at train stations would have otherwise driven their private car for the entire commute trip, while 7% would have been dropped to and collected from the station. A total of 15 tonnes of CO_2 would be saved per year for 50 daily BiTiBi service users, which equated to approximately 100,000 vehicle km/year (EEA, 2019). In the Liverpool pilot, 9% of users of the safe bike parking facilities, and 19% of users of the bike share scheme reported that they stopped driving after joining the scheme. Various studies have found that the provision of trip-end facilities such as bicycle storage and changing room facilities significantly influenced and increased the rates of cycling, principally amongst women (Van der Kloof, 2013; Pucher and Buehler, 2012; Bonham and Wilson, 2012). This project similarly estimated what the results would be in a scenario whereby 20% of rail users in the EU accessed the train stations by bike. Under this scenario test, it was estimated that 800 kilotonnes of CO_2, 55 tonnes of particulate matter and 250 tonnes of NO_x emissions would be saved as a result of a reduction in vehicle kilometres travelled of 5 billion kilometres (BiTiBi, 2017).

There exists an evident opportunity to increase the mode share of cycling and public transport services (particularly rail) by combining and better integrating these modes to cater for door-to-door trips in which walking, and cycling are common first and last mile options (F/L/O). When integrated with public transport services, the 'potential of the bicycle is no longer limited to short trips', in this way the potential of carbon emissions reductions is also increased as a result. For example, in the Netherlands 51% of commuters in the city of Utrecht use a combination of cycling and rail to get to work (Bruntlett and Bruntlett, 2018).

Walking is an alternative that is often not seriously considered as an actual transport mode in the same way that cycling and public transport are, however, it is the most basic and readily available F/L/O mile option (EEA, 2019). The majority of all trips include a walk link, either at the start, end or at both ends. Research indicates that the reach of the existing public transport system can be extended significantly simply by making walking to and from hubs and stops easier, less prone to barriers and more pleasant by creating attractive urban spaces that are well connected to public transport infrastructure (EEA, 2019).

Based on international evidence, it is believed that 400m to 500m or ¼ mile is the standard walking distance people are willing to travel in order to access public transport services, anything longer and the likelihood of another mode of transport (i.e. a private car) being selected significantly increases. While studies have also shown that people generally walk further for faster and more reliable public transport services e.g. rail. In this way there exists many cases whereby commuters are willing to take public transport, but the issue of accessibility presents a major obstacle preventing service providers from addressing the population in such areas, which are a potential untapped source of patronage for public transport providers. Improving cycling facilities and the walkability (pedestrian-friendliness) of an area can enhance the catchment radius of public transport nodes (bus stops and rail stations), which as a result addresses public transport accessibility concerns and increases patronage.

Mainstream public transport services must operate on fixed routes within a network, i.e. train/ tram tracks and bus lanes on main thoroughfares. Bruntlett and Bruntlett (2018) argue that the 'only way to deliver quality service is by having a method to feed people into that fixed stream from a larger area, something that the bicycle does exceptionally well'. The bicycle is the perfect feeder mode for inducing the demand for traditional public transport services. However, arguably the main obstacle in harnessing this latent demand is by not adequately addressing the convenience of using a bicycle for first and last mile trips, via insufficient and unsecure provision of bike parking facilities at bus and rail stations, which ultimately discourages potential cyclists to park their bike in these locations. The connectivity of these modes, which is enhanced by the associated facilities is what really matters. If a bike trip followed by a train or bus trip is more of a nuisance than a private trip, than expecting any sort of mode shift is unrealistic and improbable. Roland Kager, a transport consultant in Rotterdam states that short trips are what makes a city function, and what differentiates the bike train combination to private car-oriented mobility (Bruntlett and Bruntlett, 2018).

A key element in addressing the last mile challenge are bike share schemes like OV-Fiets in the Netherlands, whose primary purpose is to cater for first and last mile trips from train stations. Users of this scheme pay only €3.50 per day, which permits you to pick up the shared bike at the station, park it at your home overnight (last mile), and then return it to the station the next day (first mile). In this way, the convenience of accessing the train station for early morning commutes and reaching the final destination from the station in the evening (i.e. residence) is enhanced. The OV-Fiets scheme has been hailed as a success in the Netherlands with 3 million rentals being recorded per year in 310 locations (Bruntlett and Bruntlett, 2018). In other words, this essentially accounts for 3 million car journeys made per year that have transferred to bike and train modes.

Thus, this study demonstrates that valuable increases in active mode trips and rail patronage can be achieved by addressing the accessibility of the rail stations for non-car users for first and mile links. In the context of Ireland, there is an evident opportunity for Irish Rail and bike share providers to team up to enhance the accessibility of rail stations through the seamless integration of these modes via the provision of upgraded safe cycle tracks, secure and sheltered bike parking and a seamless and flexible payment system that integrates both modes.

Case study 2: Seville

During the period of 2006 to 2011 the city of Seville, Spain, experienced a rapid surge in the number of people cycling, which is reflected in a 9% increase in the mode share of cycling in this city. It was found that bike use was multiplied by a factor of approximately 6 in this same period (Marques et al, 2014). In 5 years, the city introduced a bike share scheme and expanded its network of segregated cycling facilities from 12 kilometres to 120km (see Figure 5), the majority of which are bidirectional cycle lanes which were constructed on previous roadside car parking spaces in the city. As a direct result of the investment and action taken to improve facilities for cyclists, the number of cycling trips grew from 13,000 in 2006 to 72,000 in 2011 (West Cycle, 2019).

In 2010, Seville City Council found that of this increase in cycling, 32% of the mode shift came from private car users and 5.4% came from former motorcyclists (European Cyclists' Federation, 2014).

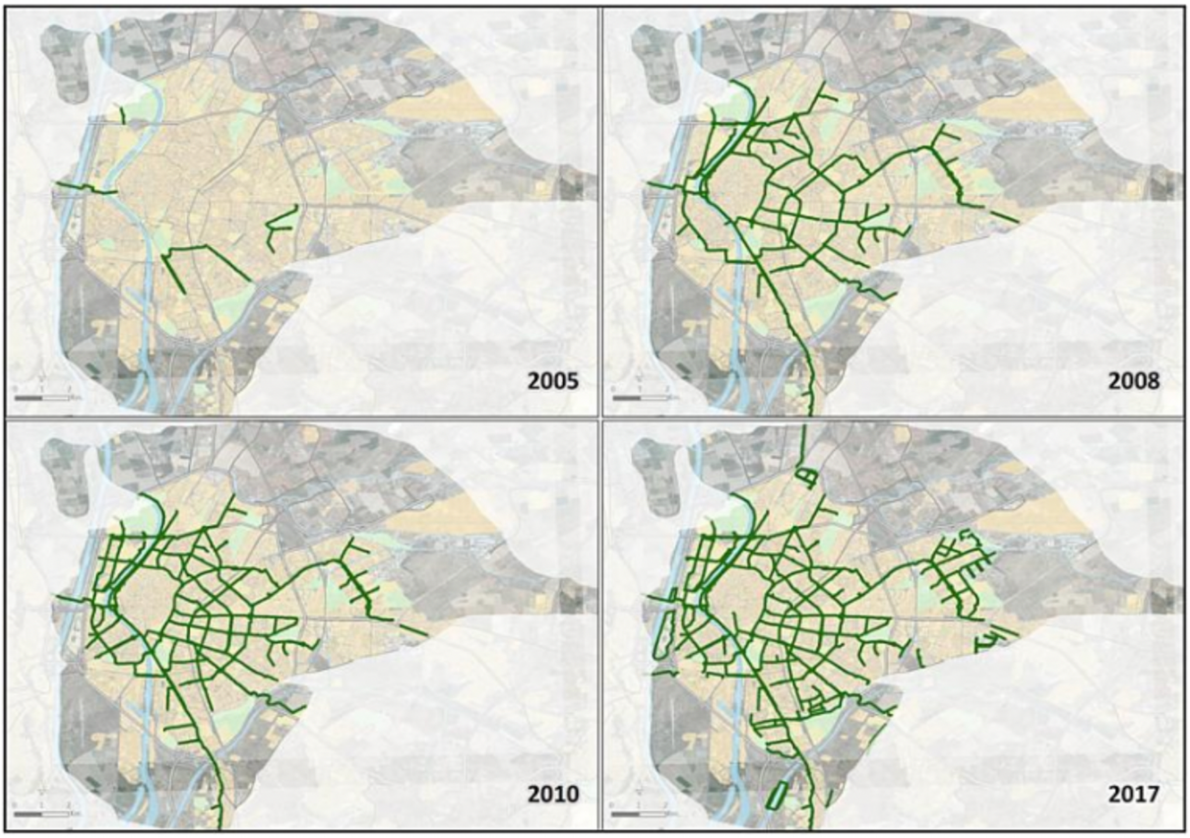

Figure 5 Expansion of the cycle network in Seville (People for Bikes, 2017)

Parking facilities, anti-theft arrangements and the separation of or lack intermodality between cycling and public transport services were found to be the elements that were most sought after by potential cyclists and as such the lack of such accommodations were seen as the main obstacles in attracting latent demand for cycling (Marques et al., 2014). Marques et al. (2014) stated that from 1990 to 2011 there was a 7.8% increase in the mode share of cycling, a 11.2% decrease in public transport and only a 1.6% increase in the private car mode share. The increase in cycling in Seville has reportedly also demonstrated the 'safety in numbers' principle, as the reduction in the perceived risk in cycling was strongly correlated with an increase in number of people cycling in the city.

The success of rapidly growing the rate of cycling in Seville in just five years has been reportedly attributable to guidelines that were established to ensure the optimal effectiveness of the network design: 1) segregation: the network was separated from other motorised traffic; 2) connectivity: main trip attractors where connected to main residential areas; 3) continuity: in order for the design to be consider a 'network' all cycle lanes were continuously linked without gaps; 4) homogeneity: the design of the network and payment was consistent throughout; 5) bidirectionality: the majority of the network's cycle lanes run in both directions (Marques et al., 2014).

The development of the cycle network, the introduction of the bike share scheme and increasing the provision of secure bicycle parking were central elements in an overall air quality plan for the city in which the aim was to encourage a shift from private cars to non-motorised modes. The integration of cycling with public transport services was similarly a key component included in the air quality plan, which was incentivised by providing discounts and preferential rates to commuters that combine cycling and trains or buses in their journey (ECF, 2014).

The experience in Seville is testament to the effectiveness of significant investment in cycling infrastructure through providing a network of continuously linked segregated cycle lanes in shifting attitudes of the safety and attractiveness of cycling, which ultimately led to a rapid increase in cycling trips.

3.2.3. Active mode usage relative to other European countries

Table 4 offers a clear comparison of walking and cycling mode shares and the overall sustainable mode share (inclusive of public transport) in the largest cities in the Netherlands, Denmark, and Ireland. The data displayed in Table 4 shows that the rates of cycling and walking in Irish cities lag far behind that being experienced even in perhaps lesser known cycling cities in the Netherlands and Denmark such as Rotterdam and Aarhus. This table similarly provides 2014 values for tonnes of CO2 per capita for each of the three countries. The results clearly demonstrate that Ireland has a much lower sustainable mode share, relative to Denmark and the Netherlands (i.e. up to 22% in Dublin vs 42% in Amsterdam), and in addition to this, Ireland's emissions per capita are greater than both other countries. This assessment is not assumed to be exhaustive, rather it serves to indicate how countries with the highest sustainable mode share in cities can also have lower emission per capita (Carroll, et al., 2019).

Table 4 Emissions and sustainable mode share comparison

Country	City	(tCO2/cap) 2014[a]	Mode Share[b]		Total sustainable mode share
			Walk	Cycle	
The Netherlands	Amsterdam	1.75	20%	22%	42%
	Rotterdam		18%	16%	34%
Denmark	Copenhagen	1.93	17%	30%	47%
	Aarhus		19%	18%	37%
Ireland	Dublin	2.27	15%	7%	22%
	Cork		15%	2%	17%

[a] World Energy Council (2019)
[b] European Platform for Mobility Management (2019)

In 2014, the European Commission conducted a study which collated data from various European household travel surveys to present an analysis of active mode use and infrastructure in Europe. Table 5 presents the walking and cycling mode shares (as a main mode of transportation) from such household survey sources for major European cities. This shows that Dublin has an above average mode share for walking and cycling relative to the other major European cities included in this study. However, it must be noted that the data presented is based on travel patterns for the fourth quarter of 2014, when the National Household Travel Survey (NHTS) was conducted.

Table 5 Walking and cycling as a main mode of transport

Country	City	City Mode Shares 2014 (%)			
		Walking[a]	diff to Average	Cycling[a]	diff to Average
Austria	Vienna	44	15.72	13	1.25
Belgium	Brussels	38.52	10.24	6.39	-5.36
Bulgaria	Sofia	27.69	-0.59	1.99	-9.76
Switzerland	Zürich	27.8	-0.48	22	10.25
Cyprus	Nicosia	17	-11.28	2.2	-9.55
Czech Republic	Prague	35.59	7.31	3.98	-7.77
Germany	Berlin	18.56	-9.72	24.55	12.80
Denmark	Copenhagen	14.29	-13.99	58.33	46.58
Estonia	Tallinn	25.8	-2.48	1.2	-10.55
Spain	Madrid	21.4	-6.88	1.8	-9.95
Finland	Helsinki	42	13.72	18.6	6.85
France	Paris (Greater City)	50.69	22.41	5.37	-6.38
Greece	Athens (Greater City)	41.7	13.42	2	-9.75
Croatia	Zagreb	26.15	-2.13	12.77	1.02
Hungary	Budapest	37.05	8.77	9.16	-2.59
Ireland	**Dublin**	**34.8**	**6.52**	**17.2**	**5.45**
Iceland	Reykjavík	15.74	-12.54	9.76	-1.99
Italy	Roma	23.6	-4.68	1	-10.75
Lithuania	Vilnius	16.6	-11.68	3	-8.75
Luxembourg	Luxembourg	41.72	13.44	8.18	-3.57
Latvia	Riga	30.54	2.26	6.39	-5.36
Malta	Valletta	13.14	-15.14	0.98	-10.77
The Netherlands	Amsterdam	24.06	-4.22	53.08	41.33
Norway	Oslo	17.8	-10.48	14.4	2.65
Poland	Warsaw	17.2	-11.08	11	-0.75
Portugal	Lisbon (Greater City)	25.85	-2.43	1.25	-10.50
Romania	Bucharest	41.72	13.44	2.4	-9.35
Sweden	Stockholm	33	4.72	16.9	5.15
Slovenia	Ljubljana	20.24	-8.04	25.93	14.18
Slovakia	Bratislava	21.6	-6.68	3.4	-8.35
United Kingdom	London	30.8	2.52	6	-5.75

[a] European Commission (2017)

In addition to walking and cycling as a main mode of transport, the European Commission study similarly reported average walking and cycling kilometres travelled per day on a country level and the average number of daily trips by each mode. The results, which are displayed in Tables 6 and 7, show that Ireland was the lowest amongst the European nations included in the study in each of these metrics - with 0.56 kms and 0.24 person walking trips per day recorded and 0.2 kms and 0.02 person cycling trips per day. These results indicate that Irish people are more inactive in our transport practices than many other European nations.

Table 6 Average daily kilometres travelled walking and cycling at country level

Average **walking** pkm per day at country level			Average **cycling** pkm per day at country level		
	Average person km per day[a]	Reference Year		Average person km per day[a]	Reference Year
Belgium	1.415	2010	Belgium	0.743	2010
Cyprus	0.558	2009	Cyprus	0.032	2009
Denmark	0.81	2014	Denmark	1.6	2014
Finland	0.99	2010-2011	Finland	0.73	2010-2011
France	0.8	2008	France	2.8	2008
Germany	1.3	2008	Germany	1.2	2008
Ireland	**0.56**	**2014**	**Ireland**	**0.2**	**2014**
Italy	3.55	2015	Latvia	3.9	2008
Latvia	2.7	2008	The Netherlands	2.55	2015
The Netherlands	0.81	2015	Norway	5.1	2013-2014
Norway	2.2	2013-2014	Slovakia	1.13	2015
Sweden	1.13	2011-2015	Sweden	0.6	2011-2015
Switzerland	2	2010	Switzerland	0.8	2010
United Kingdom	0.79	2014	United Kingdom	0.25	2014

[a] European Commission (2017)

Table 7 Average number of daily trips walking and cycling at country level

Average **walking** trips/ day in 15 countries			Average **cycling** trips/ day in 15 countries		
	Trips/day/person[a]	Reference year		Trips/day/person[a]	Reference year
Denmark	0.88	2013	Denmark	0.46	2014
Finland	0.61	2010-2011	Finland	0.24	2010-2011
Germany	0.9	2008	Germany	0.4	2008
Ireland	**0.24**	**2014**	**Ireland**	**0.02**	**2014**
Italy	2.19	2015	Italy	2.28	2015
The Netherlands	0.47	2015	The Netherlands	0.72	2015
Norway	0.7	2013-2014	Norway	0.15	2013-2014
Slovakia	1.4	2015	Slovakia	0.2	2015
Sweden	0.56	2011-2015	Sweden	0.2	2011-2015
United Kingdom	0.55	2014	United Kingdom	0.05	2014

[a] European Commission (2017)

The Copenhagenize Index of the most bicycle-friendly cities in the world, as shown in Table 8, is a strong indication of Ireland's lack of action in providing an adequate streetscape for cycling to flourish, which has hindered the potential to grow the culture of cycling in urban areas. Dublin, Ireland's only city to have made an appearance on this index, has fallen out of the top 20 bicycle friendly cities, which is arguably as a result of unclear political ambitions despite an increase in cycling trips, growing pressure from various cycling advocacy groups, and a low share of the capital transportation budget being devoted to active modes. The parameters in the generation of this index are as follows: Streetscape (bicycle infrastructure, facilities, traffic calming), culture (gender and modal split, mode share increases over the last 10 years, safety indicators, bicycle image, cargo bike use), and ambition (advocacy, politics, bike share, urban planning).

Table 8 Copenhagenize Index of Bike-friendly Cities 2015 - 2019

2015[a]	2013	2015	2017	2019
1.Copenhagen	1.Amsterdam	1.Copenhagen	1.Copenhagen	1.Copenhagen
2.Amsterdam	2.Copenhagen	2.Amsterdam	2.Utrecht	2.Amsterdam
3.Utrecht	3.Utrecht	3.Utrecht	3.Amsterdam	3.Utrecht
4.Eindhoven	4.Seville	4.Eindhoven	4.Strasbourg	4.Antwerp
5.Malmö	5.Bordeaux	5.Malmö	5.Malmö	5.Strasbourg
6.Nantes	6.Nantes	6.Nantes	6.Bordeaux	6.Bordeaux
7.Bordeaux	7.Antwerp	7.Bordeaux	7.Antwerp	7.Oslo
8.Strasbourg	8.Eindhoven	8.Strasbourg	8.Ljubljana	8.Paris
9.Antwerp	9.Malmö	9.Antwerp	9.Tokyo	9.Vienna
10.Seville	10.Berlin	10.Seville	10.Berlin	10.Helsinki
11.Barcelona	**11.Dublin**	11.Barcelona	11.Barcelona	11.Bremen
12.Ljubljana	12.Tokyo	12.Ljubljana	12.Vienna	12.Bogotá
13.Dublin	13.Munich	**13.Dublin**	13.Paris	13.Barcelona
14.Buenos Aires	14.Montréal	14.Buenos Aires	14.Seville	14.Ljubljana
15.Berlin	15.Nagoya	15.Berlin	15.Munich	15.Berlin
16.Minneapolis	16.Rio de Janeiro	16.Minneapolis	16.Nantes	16.Tokyo
17.Paris	17.Barcelona	17.Paris	17.Hamburg	17.Taipei
18.Hamburg	18.Budapest	18.Hamburg	18.Helsinki	18.Montréal
19.Munich	19.Paris	19.Munich	19.Oslo	19.Vancouver
20.Montréa	20.Hamburg	20.Montréal	20.Montréal	20.Hamburg

*Copenhagenize Index (2019)

The European Cyclists' Federation recommends that 10% of all transport investment should be devoted to spending on cycling. This has also been supported by the United Nations Environment Programme, the Joint Committee on Climate Action, the Citizen's Assembly, and many cycling advocacy groups in Ireland such as Cyclist.ie, the Dublin Cycling Campaign, and IBike Dublin.

In order to bring proportional spending on cycling in line with other European countries, a significant increase in investment is needed. To meet the 10% of the land transport capital budget for 2020, cycling would require an investment of approximately €194 million. However, to put this 10% figure into context, the ECF states that the Netherlands invests approximately '7% of its transport budget into cycling. Given the fact that the country has been promoting cycling for the past 40 years or so, investments in the order of at least 10% are justifiable in order [for Ireland] to catch up with Dutch standards' (ECF, 2014).

3.2.4. Recommendations/ Guidance on how increasing the use of active modes

There presents a greater opportunity to reduce overall carbon emissions from transport by integrating cycling and public transport services and catering for first and last mile trips, as demonstrated in the BiTiBi pilots. This has been achieved through providing sufficient sheltered and secure bike parking at rail stations, the provision of upgraded safe cycle tracks which provide safe accessibility for cyclists and pedestrians to such stations, OV-Fiets approach to flexible bike sharing secure, and the provision of a seamless and flexible payment system that integrates both modes. A bicycle theft is one of the most significant disincentives to combining cycling and public transport, thus, providing or expanding anti-theft bicycle parking facilities at rail (heavy and light rail) and bus stations, is a vital measure to implement in order to encourage intermodality and the integration of two key sustainable modes (cycling and public transport).

A mode shift from private cars to cycling can be enhanced by extending the range of active modes trips with the use of e-bikes and other micro-mobility options (i.e. electric scooters). The introduction of e-bike and e-scooter shared schemes could, in effect, extend the operational radius of regular bike share schemes and encourage a shift away from internal combustion engine vehicles (ICEV) such as private cars and motorcycles/mopeds.

During the Velocity Conference in 2019, which was hosted by Dublin, Fabian Küster - a Senior Policy Officer with the European Cyclists' Federation (ECF), addressed the Joint Committee on Climate Action. In this address he suggested the following three measures could be introduced in order to boost the uptake of cycling and e-bikes in Ireland and simulate a sustainable mode shift:

1) Introduce a national purchase subsidy, akin to the €200 subsidy available in France, which effectively doubled the sales of e-bikes in the year following its introduction and resulted in 67% of private trips being replaced by e-bikes;

2) Introduce a bicycle allowance scheme, whereby employers would financially reward their employees for using active modes, for instance in Belgium the employer can pay an employer 23 cents for every kilometre cycled to work, which has resulted in a 42% increase in cycling to working over a 12 year period, and;

3) Introduce *minimum* off-street bicycle parking standards nationally, to ensure that cheap, secure and accessible parking is available for cyclists, particularly for those who are less inclined to park their bicycles in on-street parking facilities due to the ever-present threat of bicycle theft (ECF, 2019).

An extension of the financial incentives (i.e. grants, Vehicle Registration Tax (VRT) rebates) made available for private electric cars to e-bikes and e-mopeds would be welcomed. Bike to work has been shown to be successful and is resulting in an uptake in the numbers cycling (Caulfield and Leahy, 2011). The research shows that those availing of the scheme are for the first time cycling more and switching to cycling from driving. Moreover, an increase in the €1,000 limit of the Bike to Work scheme could be introduced to facilitate the higher costs associated with e-bikes and some e-mopeds.

The licencing of electric scooters should be facilitated, with the caveat that legislation/ regulation is required regarding the establishment of safety standards. It is recommended that policy should be enacted to permit their safe use, rather than discouraging and hindering their use through prohibitive legislation and rules. Convenience and ease of use in addition to proximity to nearby docking stations, have been cited as the principal motivating factors for bike and e-scooter sharing in North America, China, the UK, and Australia (European Cyclists' Federation, 2014; Bachand-Marleau et al., 2012; Fishman et al., 2004).

It is suggested that the location of shared bicycle, e-bike and e-scooter docking stations at all rail and bus stations should be prioritised to facilitate key first and last mile journeys. In 2007, the Vélo'v bike share scheme in Lyon, France reported a 7% reduction in the mode share of private vehicle after its introduction, while the 'Bicing' shared scheme in Barcelona recorded a 1% increase in the cycling mode share since its launch and a 10% reduction in private car trips (European Cyclists' Federation, 2014).

Addressing the issue of pedestrian 'pinch points' in city centre areas, where the flow of pedestrian traffic greatly exceeds the capacity of available infrastructure requires attention. The pedestrianisation of streets with high pedestrian footfall could be examined more closely to address the needs of and improve urban air quality for pedestrians, who ultimately should be prioritised above any other mode of transport.

The response to the COVID-19 pandemic has put pressure on local authorities to provide extra space for active mode users in order to facilitate social distancing measures put in place by governments. Widened and decluttered footpaths, segregated and contra flow cycle lanes, early start signalling and cyclist priority at junctions, and optimisation of signals at junctions to enable shorter pedestrians wait times at crossings and pedestrianised plazas (i.e. College Green, Dublin), are some of the rapid changes that have come into effect, which have been widely welcomed. Such measures have been campaigned and debated for and have been the subject of numerous strategic policy documents over the past 30 years. However, the question is how permanent will these measures be, and should the interests of pedestrians and cyclists only be prioritised over motorists during a pandemic? This is a once in a generation opportunity for our regional cities to be an exemplar for safe cycling infrastructure and culture nationally. There is overwhelming evidence to suggest that the demand for cycling already exists in our cities, therefore, the forthcoming months and year are the ideal time to provide the infrastructure to match this demand.

3.2.5. Key Active Mode Findings

- The academic literature concerning active modes focuses principally on the health benefits that walking and cycling as modes of transport offer to users and society as a whole. As a result, there is a limited number of studies which emphasise and report empirical emissions savings from the uptake of active modes alone.
- In Ireland, cycling is currently poorly integrated with mainstream public transport modes, with a lack of secure, sheltered public parking facilities available at bus and rail stations across the country. There presents a greater opportunity to reduce overall carbon emissions from transport by integrating cycling and public transport services and catering for first and last mile trips, as demonstrated in the BiTiBi pilots. However, unless cycling theft is controlled and adjacent infrastructure is provided at public transport nodes, sufficiently combining these modes will be challenging.
- Experiences and lessons learned from case studies in cities such as Seville, demonstrate that change in cycling can be achieved rapidly with adequate political will and sustained investment (i.e. 10% of overall land transport budget) within one election cycle.
- Mode shift from private cars to cycling can be enhanced by extending the range of active modes trips via the use of e-bikes and other micro-mobility options. Thus, their use should be legalised in conjunction with safety regulations. Fiscal incentives furnished to EV motorists should be extended to e-bike and e-scooter users in order to encourage their use.
- Current national active modes targets and objectives in Ireland rely on the successful design, implementation and investment of large public transport projects such as BusConnects in order to deliver improvements in walking and cycling infrastructure. More imagination, commitment and a responsibility from local authorities is required to implement the infrastructural changes to support and sustain the growth demand for cycling.

3.3 Public transport

3.3.1 Public transport as a means to reduce emissions

In Ireland, public transport plays a vital role for commuting to work and education, connecting communities, and providing a sustainable means of travel. In 2018, over 264.8 million public transport trips were recorded in Ireland (DTTAS, 2019a). Table 9 shows the changes in public transport usage over a 20-year period using commuting to work data from the Census. The data shows that in this period public transport made up approximately 20-22% of the travel to work mode share and that in the regional cities it was more or less half of what it was in Dublin.

Table 9 Public Transport Mode Shares for trips to work (1996-2016)

	Bus Mode Shares (%)				
	1996	**2002**	**2006**	**2011**	**2016**
Dublin	18.46	16.86	15.68	14.22	14.12
Cork	12.55	9.77	8.80	7.68	8.02
Limerick	13.46	10.31	9.07	7.00	6.99
Galway	14.98	12.39	10.19	9.14	8.90
Waterford	11.55	9.57	7.75	6.70	6.18
	Rail Mode Shares (%)				
Dublin	3.67	4.17	6.51	6.53	6.82
Cork	0.46	0.36	0.43	0.54	0.62
Limerick	0.11	0.08	0.12	0.16	0.15
Galway	0.12	0.12	0.25	0.28	0.37
Waterford	0.10	0.07	0.11	0.13	0.17
	Mode share of Public Transport (%)				
Dublin	22.13	21.03	22.19	20.75	20.94
Cork	13.01	10.13	9.23	8.22	8.64
Limerick	13.57	10.39	9.19	7.16	7.14
Galway	15.10	12.51	10.44	9.42	9.27
Waterford	11.65	9.64	7.86	6.83	6.35

Public transport has a central role in Ireland's strategy to reduce carbon emissions and there is significant investment in public transport outlined in the Government's Capital Plan, including Metrolink and BusConnects. Analysis conducted by the National Transport Authority estimates that a daily reduction of 44 tonnes of CO_2 could be achieved from implementing the BusConnects project in its entirety. Public transport presents the most attainable and equitable opportunity to achieve a decarbonisation strategy in the transport sector. Considerable reductions in carbon emissions may be realised through increasing the number of EVs in the car fleet, but those reductions are dependent upon technological progress and declining battery costs, while reductions from public transport can be achieved more quickly (Yang et al, 2017). Yang et al, in a study of policies to reduce carbon emissions from transport in China, pointed out that the reductions achieved by increasing EVs are more impressive and greater than those achieved by increasing public transport use and active travel but take longer and cannot be realised with current technology. Therefore, it is still important, even in a scenario where EVs become more widely available, to continue to invest in public transport and to bring about reductions in carbon emissions more quickly through a combination of measures. Public transport investment can result in a shift from private car to more sustainable modes for those trips that are beyond the walking and cycling distances

When considering the role of public transport in reducing carbon emissions, consideration must also be given to the public transport fleet, and what that should look like over the next decade in order to maximise the potential carbon emission reductions that can be achieved from greater public transport use.

3.3.2 Improving the carbon emissions of the public transport fleet

The CAP (Government of Ireland, 2019) sets out objectives of procuring 1,200 low-emission buses in cities by 2030 and the National Development Plan set out a commitment that Ireland would stop purchasing diesel-only buses from July 2019 (Department of Transport, Tourism and Sport, 2019b; Byrne Ó Cléirigh Consulting, 2019). However, when considering the introduction of cleaner public transport vehicles, research has demonstrated that the impact on carbon emissions may be considerably less when the lifecycle of the vehicle is considered and that the choice of alternative fuel has a very strong impact on the potential for carbon emission reduction (Ercan et al, 2015; Xylia et al, 2019; Byrne Ó Cléirigh Consulting, 2019).

For example, Xylia et al (2019) show that in Sweden, second generation biofuel buses have the potential to achieve effective emission reductions, at a much lower costs than electrification of the bus network and recommend that a mixture of biofuels and EVs offers the best solution, with electric buses being retained for use in urban centres where air quality is more important. Dong et al (2018) also describe the importance of alternative fuel buses in reducing carbon emissions, but state that increasing numbers of energy-efficient electric buses must be accompanied by ensuring decreased reliance on fossil fuels for generation of electricity.

In Ireland, a review of the performance of alternative fuel buses was conducted by the DTTAS in 2018 (Byrne Ó Cléirigh Consulting, 2019). That study found that electric buses, followed by diesel electric-hybrid buses were the most energy efficient in an Irish context, with compressed natural gas (CNG) buses being the least energy efficient; and that electric buses were the best performers for carbon emissions, both at tailpipe and when an LCA was performed, with diesel electric-hybrid buses performing next best. However, if biofuels, such as biodiesel and biomethane, are used, significant reductions in carbon emissions can be achieved with hybrid and bioCNG buses. The report concludes that a fully electric fleet offers the best options for reducing carbon emissions, improving air quality and increasing renewable energy use.

3.3.3 Incentivising Public Transport, discouraging car use

Research shows that reducing carbon emissions through better public transport and more use of public transport is a medium to long term strategy and must be supported by additional measures that promote a reduction in car use and car ownership (Zhang and Zhao, 2018).

Many cities recognise the importance of public transport in reducing carbon emissions, if a significant modal shift from car to public transport can be realised (Anh Nguyen et al, 2018). Bringing about that modal shift can be achieved by investment in good quality public transport, by incentivising public transport use and by discouraging car use. Research by Conti (2018) demonstrates that cost is important in incentivising public transport, and found, in a study in France, that bigger shifts from car to public transport came from reducing costs, rather than travel time. Considering how public transport use might be incentivised, Cools et al (2016) described how free public transport can bring about modal shifts from car to public transport, although they described how cheap public transport does not result in a shift, concluding that "*subsidizing of public transport with the aim of making it free seems to be an effective measure to increase the use of public transport. Subsidizing public transport with the aim of making it* *less expensive or to change the relative prices with regard to car usage does not seem to be an appropriate measure for policy makers"*.

Incentivising public transport is more likely to result in a modal shift to public transport if accompanied by some restrictions to the car, or associated increases in car use costs (Conti, 2018; Hammadou and Papaix, 2015; Carroll et al, 2019; Yang et al, 2017), in particular if income from indirect measures such as carbon tax and parking charges can be used to improve public transport performance (Hammadou and Papaix, 2015).

In research looking at the potential for public transport to reduce carbon emissions in the city of Shenzhen in China, Zhang and Zhao (2018) found that the city could bring about significant reduction in carbon emissions by introducing a combination of policies such as introducing strict car quotas, better fuel standards for public transport, tax, and infrastructure measures to encourage EVs and improving public transport infrastructure. It was the combination of these measures that resulted in real and significant decreases in carbon emissions, amounting to 8.05 Mt carbon by 2030. The policies with the greatest impacts were introducing strong car ownership controls and better fuel standards in public transport vehicles.

3.3.4 Better infrastructure

Cities with ambitious plans to reduce carbon emissions include Copenhagen (Copenhagen 2025 CAP – aiming for 75% of trips to be by public transport or active modes by 2025), Adelaide (The 30 year plan for Greater Adelaide – aiming for a carbon neutral city), and improving public transport infrastructure is very important in those plans.

In Adelaide, for example, public transport, and especially rail-based public transport, is seen as being very important in bringing about a reduction in car use, with clear objectives to move car users to tram services. Ahn Nguyen et al (2018) consider the potential impacts of extensions to Adelaide's electric tram system on carbon emissions and modal share, finding that 66.7% of current car users would shift to tram, resulting in a decrease of 8.96% in carbon emissions. Similarly, in Shanghai, Zhang et al (2018) recommend that investment in rail transit has greater potential to achieve higher modal shift from car and reduced carbon emissions than investment in bus services.

These aforementioned studies did not consider the carbon emissions associated with improving public transport infrastructure. Ghate and Qamar (2020) consider a life cycle analysis of Bus Rapid Transit (BRT), metro and rail systems in Indian cities, finding that metro and rail systems achieve greater reductions in carbon emissions based on tail-pipe emissions and are more energy efficient than BRT. However, when carbon associated with the total life cycle is assessed, they found that metro systems have much higher carbon emissions per passenger kilometre than BRT systems, mainly because electrical generation in India is still by coal. Ghate and Qamar (2020) advocate that LCA is very important for the transport sector when considering carbon emissions and it is only through a LCA that a true understanding of carbon emissions related to infrastructure development can be obtained. Some of the carbon associated with construction of a metro system can be reduced or mitigated through use of better materials and through more sustainable construction approaches.

3.3.5 Free Public Transport

Many cities recognise the importance of public transport in reducing carbon emissions, if a significant modal shift from car to public transport can be realised (Anh Nguyen et al, 2018). Bringing about that modal shift can be achieved by investment in good quality public transport, by incentivising public transport use, and by discouraging car use. Research by Conti (2018) demonstrates that cost is important in incentivising public transport, and found, in a study in France, that bigger shifts from car to public transport came from reducing costs, rather than travel time. Considering how public transport use might be incentivised, Cools et al (2016) describe how free public transport can bring about modal shifts from car to public transport, although they describe how cheap public transport does not result in a shift, concluding that "*subsidizing of public transport with the aim of making it free seems to be an effective measure to increase the use of public transport. Subsidizing public transport with the aim of making it less expensive or to change the relative prices with regard to car usage does not seem to be an appropriate measure for policy makers"*. This research by Cools et al, however, is based on a small study and the costs and potential impacts of introducing free public transport need to be assessed rigorously before introducing such policies in Ireland. In particular, it is important to evaluate if free public transport brings about a modal shift from car to public transport, or if the increase in public transport use is from a reduction in walking and cycling.

A number of cities and one country have introduced free public transport. For example, Tallinn in Estonia introduced no-fare public transport in 2013 (Cats et al, 2017). This resulted in increased use of public transport with 14% more trips on public transport in the year that followed, and a reduction of 10% in the number of car trips in the city. However, free public transport also negatively impacted upon walking trips, with a reduction of 40% in walking trips. The biggest impacts were on younger people, older people, the unemployed, and those on lower incomes. For these groups, there were increases in mobility and the policy of free public transport was seen to have significant equity effects. While introducing fare-free public transport represents a cost and more evidence is required to evaluate the potential impacts on modal shift, in a country considering incentivising the purchase of EV vehicles, investment in cheaper or free public transport use, might be considered to have greater impacts on equity and to improve mobility of those on the lowest income levels, while incentives to purchase EVs are more likely to impact upon the wealthier in society. In 2018, in France, Dunkirk made public transport free, with trips on buses increasing by 65% on weekdays and 125% on weekends, again with those on lower incomes experiencing the greatest benefits (Modijefski, 2019). In 2020, Luxembourg became the first country to introduce free public transport for all travel, except first class train fares and night buses. It is too soon to evaluate the impacts of this on modal shift or carbon emissions, but the objectives were to increase public transport use in a country with very high car use and car ownership, at what the government saw as a relatively low cost. Public transport operating costs stand at approximately €500 million per year in Luxembourg, but revenue from ticket sales was only €41 million (BBC, 2019). In Dunkirk, the moderately low contribution of ticket sales to the running costs of public transport (approximately 10%) was also cited as a justification of the choice to make public transport free (Modijefski, 2019).

Introducing free public transport may result in increased public transport use but what is much clearer from existing research it that incentivising public transport is more likely to result in a modal shift to public transport if accompanied by some restrictions to the car, or associated increases in car use costs (Conti, 2018; Hammadou and Papaix, 2015; Carroll et al, 2019; Yang et al, 2017), in particular if income from indirect measures such as carbon tax and parking charges can be used to improve public transport performance (Hammadou and Papaix, 2015). It is not sufficient to make public transport cheaper (or free) or better public transport without accompanying measures to disincentivise car use (Cass et al, 2016).

3.3.6 Land Use and Public Transport Provision

Land use and public transport provision are inextricably linked. As the density of population increases, so too does the viability to provide high capacity public transport like DART or Luas. However, the opposite is also true and that in rural areas it becomes more difficult to provide frequent high-quality public transport services. The density of population in Ireland is 70.65 people per sq. km compared to the EU average of 105.41 per sq.km (World Bank, 2020). Our dispersed settlement pattern and a lack of coordinated transport and land use planning in the past has resulted in many people living great distances from frequent public transport and high levels of multiple car ownership (Caulfield and Ahern, 2014). Given this dispersed population and longer travel distances it is important that we focus on public transport as the key sustainable transport option as walking and cycling, as ideal and efficient as they are, cannot move as many people over the distances required (Friman et al, 2019).

Public transport provision in densely populated areas is one of the key drivers of social, economic and environmental development (Gallo, 2020). Internationally, several studies have examined how providing improved public transport services can result in a decrease in car usage and emissions in more urban areas. De Gruyter et al, (2020) demonstrated that residential developments within a 300-400m distance of high quality public transport were shown to have lower levels of car ownership in Melbourne. A similar study in Copenhagen showed a similar result of a 2-3% reduction in car ownership as a result of metro expansion (Mulalic and Rouwendal, 2020). While Malta has a low population it is one of the most densely populated countries in Europe (World Bank, 2020). Attard (2012) presents a case study of Malta showing how the redesign of the entire bus network and an upgrading of the fleet to Euro V buses resulted in a 47% reduction of hydrocarbons.

The introduction of new rail and other high capacity public transport systems have been shown to result in densification of population adjacent to rail stations in urban areas. Adolphson and Fröidh (2019) in a Swedish study showed that, in urban areas, new rail stations resulted in strong agglomeration tendencies in the local area.

3.3.8 Key Findings – Public Transport

- Public transport can play a significant and important role in reducing carbon emissions, if a modal shift from car to public transport is achieved.
- Better infrastructure, free public transport and integrated systems can help to achieve a shift from car to public transport.
- For modal shift from car to public transport to be achieved, improvements in public transport infrastructure should be associated with disincentives for car use and car ownership.
- Indirect measures, such as carbon taxes and increased parking charges, can assist in shifting trips from car to public transport. Income from these indirect measures should be used to improve public transport offerings.
- Public transport is best placed to achieve reductions in carbon emissions as part of an overall strategy, including EVs, disincentives for car use and indirect policies, such as carbon tax, parking charges etc.

- Careful consideration, including life cycle analysis, needs to be given to the most appropriate mix of public transport vehicles that will reduce carbon emissions in our cities.
- Electrification of bus networks can be a costly option for changing the public transport network, while hybrid and biofuel vehicles may achieve reductions in carbon emissions at a lower cost and more quickly. The particular circumstances of a city need to be assessed carefully.
- Building metros and rail systems can achieve very high reduction of carbon emission when only operating emissions are considered: however, when a total LCA is conducted, BRT and other bus-based systems may give higher reductions in carbon emission per passenger kilometre, at lower construction costs.
- To reduce carbon emissions from public transport, consideration should be given to improving construction methods and to the materials used in the construction of infrastructure, in particular in relation to major projects, such as metro systems.

4. Travel Demand Management Strategies

4.1 Working from home (WFH)

The census of Ireland collects data on the means of travel to work, however the question in the census relates to the main mode of transport used and it doesn't take into account any variation throughout the working week. This means that the data collected would not pick up information on individuals that may work from home one or two days a week, or indeed may use public transport if they use these modes less frequently then for example driving alone.

Table 10 shows the numbers of people indicating they worked from home (5 days a week) in 2011 and 2016. The numbers show that nationally, approximately 3% of the population work from home. The results are broken down by region in Ireland and they show that Dublin has the lowest percentage of people working from home (WFH) with the South-East having the highest, both in 2011 and 2016. The data in Table 10 is presented in regions rather than in the cities as with previous tables, this is due to the large amount of WFH that happens outside of the regional cities. While the data in Table 10 is useful to show the breakdown in the regions, it does not capture the numbers of people that said they work from home on a less frequent basis.

Table 10 Working from home in Ireland

Area	2011		2016	
	N	% in the area WFH	N	% in the area WFH
State	84,427	3.0	96,057	3.1
Border	8,438	3.7	9,137	3.8
Midland	6,404	3.8	6,664	3.6
West	10,087	3.7	10,999	3.8
Dublin	12,322	1.5	14,692	1.7
Mid-East	10,602	2.6	12,748	2.8
Mid-West	11,412	4.1	12,451	4.2
South-East	10,038	4.2	11,745	4.5
South-West	15,124	3.7	17,621	4.0

4.1.1 Emissions savings from WFH

Several research papers have been completed on WFH in Ireland examining its potential to change how and where we work. WFH in Ireland has been shown to have potential for reducing energy demand and emissions, particularly due to the rollout of broadband and cloud computing facilities (Fu et al, (2012)). Hynes (2016) examines WFH using a sociotechnical transitions approach to determine why it hasn't grown as some had predicted. The research finds that a lack of workplace policy on WFH results in it lacking legitimacy in the eyes of both managers and co-workers. It is concluded that this is one of the main factors holding back the growth of WFH. Caulfield (2015) examined the factors that potentially impact upon the propensity to WFH in the GDA. The research used census data and showed that those in more affluent areas and with poor public transport availability impacted upon the likelihood of WFH. The research also found, unsurprisingly, that WFH rates were higher in areas with a higher level of broadband access. O'Keefe et al (2016) conducted further research on WFH in the GDA by means of a survey and found that 44% of the sample WFH at least once a month. The research used the distance travelled by the survey respondents, mode of transport used, and an emissions factor for that mode to estimate emissions saved by WFH. The findings of a sensitivity analysis showed that if workers worked from home one or two days a week, it could result in substantial emissions savings. This approach was updated by Convery et al (2020) and measured that on average WFH one day a week for a year could result in 0.15 tonnes of CO_2 saved per annum. It is this value that will be used in the scenario analysis presented in this section.

While many studies report the potential benefits of emissions reductions from WFH, some studies show that this may not be the case. Some evidence shows that those that WFH may end up reducing commuting times, but they can experience an increase in non-work trips, which may negate any emissions reductions (Cerqueira et al, 2020). Cerqueira et al, (2020) study in the UK found that non-work trips increased as those who WFH tended to live in more remote areas. Budnitz et al (2020) also showed this trend when looking at English travel survey data as they also showed this increase in non-work trips. In a 2007 study from Finland this finding was replicated in that the probability of WFH increased with distance lived in relation to the workplace (Helminen and Ristimäki, 2007). In some cases this increase in the number of trips can be positive and that they can be taken by active modes (Chakrabarti, 2018).

Many of the early studies conducted on WFH and working from remote hubs in the mid 1990's, in the United States, showed while there was an increase in non-work trips, the subsequent travel time saved and emissions reductions made up for this increase (Henderson and Mokhtarian, 1996; Koenig et al, 1996). This trend of results has continued and the conversation on WFH has continued. More recent studies also argue the environmental benefits of WFH. Shabanpour et al (2018) in a study in Chicago found that flexible WFH could result in an almost 1% reduction in emissions and it can also reduce congestion. Hofer et al, (2018) examined a number of pathways to reduce emissions including scrapping older cars, promoting EVs and WFH. The study showed that WFH could be a very effective way of reducing emissions and that the secondary impacts of reduced congestion in the peak-period. With a new era of work practices and ever more connected cities it has been forecasted that WFH will become more popular (Hopkins and McKay, 2019).

Hynes (2014) discusses the lack of a clear public policy on WFH and indicates this could be a factor in the lack of growth in this area. Prior to the COVID pandemic there had been little direction from the government on WFH and this is seen in the CAP as it makes no reference to WFH in any of the transport actions contained in the report. However, progress in this area is likely to escalate due to the pandemic. One of the largest policy documents on WFH was published in 2019 by the Department of Business, Enterprise and Innovation. This study conducted a survey of over 3,500 workers across Ireland to determine if they worked from home and if so, how often. The results showed that 48.5% of the sample did WFH and of those that did, half did so weekly and a quarter did so every day. Of those that did WFH 63% were in the private sector and 28% in the public sector. Finally, when asked what was the main motivator for WFH, flexibility of schedule and reduced commuting times were shown as the biggest motivators.

4.1.2 Analysis of WFH Scenarios

This section of the report examines the potential emission savings from WFH. In this analysis the private and public sectors are examined using a number of scenarios. The methodology used to estimate these emissions savings can be found in Appendix II.

In Q4 2019, 412,200 people worked in the public sector (CSO, 2020). The numbers broken down by each section are presented in Table 11. The scenarios examine the potential reductions in emissions from 20, 50 and 80% of staff in the public sector WFH one or two days a week. The 80% value was used in this analysis based upon a study produced by NUI Galway that surveyed over 7,000 people during the COVID-19 pandemic that said they would like to continue to WFH after the pandemic (NUIG, 2020). The 20% value relates to the ambition in the 2020 Programme for Government that the public sector move to 20% WFH (Merrion Street, 2020).

The Defence forces, An Garda Siochana, the Health Service and those working in Education (with the exception of academics in third level institutions) have been removed from this analysis. Data was not available at a granular enough level to determine if some roles in these areas could be done remotely and it is recommended that further research be conducted in these areas. The results in Table 11 do show if policies of WFH were embraced that substantial emissions savings could be realised even with the modest WFH scenarios.

The results presented below come with the following caveats:

- One should note that this may be seen as an over simplistic approach to estimating emissions and it has been noted this could result in over optimistic results (Kin et al, 2015). So, with this in mind the results presented in this section are just for illustration and a more detailed study would be required to produce more robust results.
- That the emissions saved relate only to transport emissions. The values below do not take into account the extra energy consumed while WFH or any trips that may take place while WFH.
- As no detailed information was available on the locations of these employees so national averages for distance, vehicle fuel type and mode share was used for the estimation (more details in Appendix II).

Table 11 Scenario Analysis of WFH for Public Sector workers

Sector	Number of employees*	20% of all staff WFH 5 days a week****	20% of staff WFH – 1 day a week	50% of staff WFH – 1 day a week	20% of staff WFH – 2 days a week	50% of staff WFH – 2 days a week
		Kiloton of CO_2 reduced	Kiloton of CO_2 reduced	Kiloton of CO_2 reduced	Kiloton of CO_2 reduced	Kiloton of CO_2 reduced
Civil service	44,400	4.05	0.81	2.04	1.64	4.09
**Defence	9,100	-	-	-	-	-
**Garda Siochana	14,700	-	-	-	-	-
**Education (except third level academics)	92,478	-	-	-	-	-
***Third level academics	23,122	2.2	0.44	1.09	0.88	2.19
Regional bodies	35,000	3.3	0.66	1.66	1.33	3.32
**Health	137,200	-	-	-	-	-
Semi-State companies	56,300	5.05	1.01	2.67	2.13	5.34
Commercial Semi-State companies	41,800	3.95	0.79	1.98	1.58	3.96
Non-commercial Semi-State companies	14,600	1.39	0.277	0.69	0.55	1.38
Total	**412,200**	19.94	3.987	10.13	8.11	20.28

*Numbers as of Q4 2019 (CSO, 2020)
**Employees in these groups have been removed due to the unsuitability of these professions to work from home
*** Higher Education Authority (2019)
**** PFG

The second set of WFH scenarios uses data on the whole workforce in Ireland (public and private sectors) collected by the CSO. In conducting this analysis it was determined that assuming all professions could, WFH could result in distorted values. Therefore in order to provide a more realistic result the literature was consulted to determine which professions were most likely to WFH. Typically in Ireland, those that have traditionally worked from home have tended to be in the higher professional socio-economic groups (Fu et al, 2012; Caulfield, 2015). Crowley and Doran (2020) presents the most recent research on which professions are most likely to WFH in Ireland. The authors of this paper were consulted during the estimation of the results below. Table 12 outlines the professions deemed to be the most compatible with WFH. The scenarios used in Table 11 are replicated in Table 12. The results replicate those in Table 11 and show that even with lower percentages WFH could result in substantial emissions reductions.

Table 12 Scenario Analysis of WFH for all workers

Sector	Number of employees*	20% of staff WFH – 1 day a week	50% of staff WFH – 1 day a week	20% of staff WFH – 2 days a week	50% of staff WFH – 2 days a week
		Kiloton of CO_2 reduced	Kiloton of CO_2 reduced	Kiloton of CO_2 reduced	Kiloton of CO_2 reduced
Information and communication (J)	127,600	2.37	5.93	4.74	11.86
Financial and insurance activities (K) & Real estate activities (L)	115,100	2.14	5.35	4.28	10.69
Professional, scientific and technical activities (M)	141,100	2.62	6.52	8.56	21.39
Education (P)	191,600	3.56	8.90	7.12	17.80
Other NACE activities (R to U)	118,700	2.21	5.51	4.41	11.03
Total	694,100	12.90	32.25	29.11	72.77

*Numbers as of Q4 2019 (CSO, 2020)

4.1.3 Key findings – WFH

- Research conducted internationally on WFH demonstrates that considerable emission savings could be realised from supporting such a policy in Ireland.
- Research conducted in Ireland demonstrated that take up of WFH has been low to date and that it is specific industries that are most likely to engage in this practice.
- Studies that have been conducted in Ireland and internationally since the COVID-19 pandemic hit demonstrate that there is an increased appetite for WFH and when the pandemic passes this should be examined in greater detail.
- The analysis conducted for this document demonstrates that there is potential to reduce significant emissions by WFH - however further research is required to this area to determine the feasibility of such a policy.

4.2. Road pricing

Travel demand management (TDM) and mobility management (MM) measures are common methods of policy intervention that employ both incentives (carrots) and disincentives (sticks) as tools to encourage changes in travel behaviour or mode choice. Such tactics often combine improvements in information provision for travellers, discounted ticketing or service frequency with pricing or charging mechanisms to 'increase network efficiency by shifting travel demand to reduce peak loads and avoid or reduce congestion' (Gross et al., 2009; Howey et al, 2010). TDM approaches seek to modify travel patterns through the introduction of a range of measures that: stimulate a reduction in trips made, trip length and certain vehicle use, increase the occupancy of public transport services and active modes use, and encourage the offset of travel at peak hours in order to redistribute travel to non-peak times of the day to reduce the number of trips made at morning and evening peak times (NTA, 2015). Demand management schemes, as the name suggests, differ from supply focused approaches that seek to add additional capacity to transport infrastructure (e.g. via road building, public transport services), as TDM aims to encourage change to individual travel behaviour and mode choice. The ultimate aim of such an approach is 'to reduce the growth in demand for travel while maintaining economic progress' and encourage a transfer of trips from private cars to sustainable modes, as 'physical planning policies and measures can only partially reduce demand for travel' (DTO, 2001). Evidence suggests that in addition to reducing traffic volumes and increasing vehicle occupancy, congestion charging, parking restrictions, and pedestrianisation are also effective in mitigating the side-effects or rebound effects of reductions in congestion, available road capacities and increases in trip making, and thus vehicle kilometre travelled (Gross et al., 2009; Howey et al, 2010).

Structural policies such as laws and regulations, economic market-based instruments or changes to the physical environment (heavy infrastructure provision and urban design) are examples of the type of interventions included in TDM approaches (Eriksson et al., 2010). Travel and mobility management plans, for instance, typically incorporate a range of policy mechanisms designed as a means of introducing transport planning to a specific site such as a school, workplace or shopping centre etc for students, employees and the public. An example of this in Ireland is set out in the NTA's travel plan guide (2012), which comes under the NTA's Smarter Travel Workplaces Initiative. These plans are generally 'targeted at a specific site by an agent with a strong relationship with the local transport users to deliver transport and wider goals to the organisation and society as a whole' (Enoch, 2012).

BusConnects, Metrolink, and the DART expansion are supply oriented schemes that seek to offer more alternatives to the private car and expand and improve upon existing transport networks. These projects, which are essential in upgrading critical public transport infrastructure and service provision, are key in supporting demand management measures. Similarly, by providing more alternatives to single occupancy vehicle trips, it presents a more equitable case for considering fiscal based demand measures. Hence, more investment and commitment to continued upgrades in public transport infrastructure will be required beyond the objectives set out in the NDP. For example, the Greater Dublin Area Transport Strategy (NTA, 2016) and the National Development Plan (2018) also consider light rail Luas expansions to Bray, Finglas, Lucan, and Poolbeg, and light rail line options have also been considered for Cork. To address equity concerns associated with the introduction of, for example a congestion charge or low emission zone, financial commitment to such public transport schemes in the GDA and in other regional cities would be required to provide adequate alternatives to the private car and capacity to meet the demand. Relative to our European neighbours, Ireland critically lacks in the department of demand-oriented transport policy making and provision, which is a tool that is accepted amongst academics as appropriate to control the demand for private car trips in densely populated urban areas.

4.2.1 Pricing congestion, emissions and road space

A key consideration presented in this report, is the reality that the achievements of climate or emissions targets are unlikely to be met by advances in technology alone as a result of rebound effects (Dray et al., 2012; Hill et al., 2012). Thus, a holistic solution consisting of an 'integrated mix of market-based, command-and-control and soft policy measures' as proposed in the literature (Nunes et al, 2019), would be the most appropriate action to take to achieve meaningful emissions reductions from transport in Ireland. Indeed, it is acknowledged that many soft policies devised to encourage sustainable mode usage are found to be not fully effective as they fail to adequately recognise the behavioural elements involved in mode choice and travel decision making (Garcia-Sierra et al., 2015). Hence, while instruments that instigate behaviour change from an incentivisation approach are required, they must be positioned alongside economic ‘market-based’ fiscal measures, in order for the objectives of travel demand management to be optimised. The Dublin Transportation Office ‘Platform for Change’ document (2001) stated that by ‘going ahead with the infrastructure element [of the strategy] alone will not be enough. It must be accompanied by the demand management element and the complementary policies if the Strategy is to achieve its overall objectives’.

Of the many negative externalities associated with private car use, traffic congestion is the costliest (Small and Verhoef, 2007), as such methods of controlling the demand for private car travel is a key element of urban road pricing policy (Anas and Lindsey, 2011). In the context of Ireland, the cost of congestion, as a result of the value of time lost in the GDA was estimated to be €358 million assuming 2012 as the base year, which is projected to increase to approximately €2.08 billion by the year 2033 (DTTAS, 2017). While they may be sensitive interventions politically, disincentives which appropriately price private car travel and the space required for parking are required. This is particularly the case for free workplace parking, which is a key determinant of car mode choice in the GDA. The following measures are examples of the type of interventions that have been demonstrated as being most effective in engendering travel behaviour change: road pricing mechanisms (e.g. M50 multi-point tolling, Port Tunnel, Low Emissions Zones tariffs, congestion charging), restrictions on free-workplace parking, the abolishment of minimum parking requirements for off-street parking and the introduction of *maximum* parking requirements. Changes to fuel taxes/excise duty (diesel ban, carbon tax and reward scheme) and pricing on-street parking at its marginal cost which should be location and time dependent (i.e. sum of costs of providing the space and external costs: cruising times searching for spaces adding to congestion, the valuable city centre space lost and air quality and emissions costs) (OECD, 2018). Thus, there exists an apparent need to restrict or in some instances eliminate such free workplace parking in city centre areas (NTA, 2012). Parking restraint from the perspective of providing free parking at schools, colleges and workplaces is an issue that must be seriously considered by the government, particularly in relation to the public and civil service. On-street parking in inner city urban areas should always be charged at a premium to reflect the convenience and cost associated with the location of parking space. Marginal pricing similarly applies to positive externalities, for example, reducing public transport fares to reflect the positive effect it has on the functioning of the transport network, and to reward individuals for making such a choice (Mohring, 1972).

These measures have proved to be successful in addressing the apparent under-pricing of the externalities of car use in urban areas, which not only deter car use for certain trip purposes, but similarly influence residential choices, as people are more inclined to live further away from urban centres and their place of employment if it is convenient to drive to work and park there. Washbrook, et al. (2006) conducted a stated preference (SP) study in Vancouver, Canada, which examined the behavioural effects of introducing road pricing and parking charges in a choice set of driving alone, carpooling or an express bus service. In this study it was found that employing road pricing and parking charges would have the effect of stimulating more reductions in the demand for single occupancy vehicle trips than any other measures delivering time and cost savings to other modes such as carpooling. In other words, Washbrook, et al. (2006) found that in the context of Vancouver, travel demand management disincentives performed better than incentives in reducing car use.

Cordon pricing is a popular method in which to implement a congestion charge, with examples including, London, Stockholm, Singapore, and Milan. This method charges all motorists when and each time they enter (and sometimes also when they leave) a defined boundary, for example the central London, Stockholm, and Milan congestion charge. Zonal (e.g. low emissions zone) schemes differ slightly in that usually some motorists (i.e. motorists driving a particular vehicle) pay a daily charge to travel into, out of or within a zone, for example, the London's inner city centre ultra-low emission zone. London, Stockholm, and Milan are popular examples of where congestion charging has been successful in changing attitudes towards hard measures or disincentives to private car use. London congestion charge was introduced in 2003 and in the first two years of the London congestion charge CO_2 emissions were reduced by 19%, with NO_x and PM_{10} reduced by 12%, which was a direct result of a 34% reduction in car trips in the city (Anas and Lindsey, 2011). Stockholm introduced its congestion charge in 2006 on a trial basis, and then permanently in 2007 following widespread public support for the trial scheme. The emissions savings in Stockholm were similar to those recorded in London, with a 14% reduction in CO_2, 8.5% in NO_x and 13% in PM_{10} recorded in the years immediately following its implementation. While Milan's Ecopass scheme, which was introduced as a trial in 2008, achieved savings of 15% in CO_2, 14% in NO_x, and 19% in PM_{10}. It should also be noted that Milan's scheme was introduced with the primary aim of improving urban air quality, via lowering particulate matter and NO_x emissions, rather than congestion, hence, it this way it acts as both a congestion charge and a low emissions zone (LEZ).

Tögel and Špička (2014) found that the majority of cities in Europe have reached their highest level of outdoor air pollution in recent decades. As a result, they have stated that Low Emission or Clean Area Zones are currently the most viable solution in tackling this issue and enhancing the air quality within urban areas. They unlock 'far-reaching benefits such as better air quality, inclusive cities and a truly green future not based on fossil fuels' (ECF, 2020). For example, the ultra-LEZ implemented in 2019 in London has resulted in a reduction of 6% (12,300 tonnes) in CO_2 and 35% (230 tonnes) in NO_x emissions as a result of a reduction in traffic flows in central London (3-9% from May 2019 to January 2020) (Mayor of London, 2020). LEZs normally focus on reducing NO_x and PM_{10} emissions from highly polluting vehicles, which differs from congestion charging, that restrict the number of vehicles entering into a defined part of the city. The LEZ in operation in Milan, is slightly different to regular LEZs, as it reduces the number of vehicles entering the city, while also restricting certain vehicle types (i.e. based on engine or fuel type). As a result of this, a reduction of up to 22% in CO_2 emissions has been recorded (Urban Access Regulations in Europe, 2020). In the context of Ireland, if a reduction in transport tailpipe emissions is to be achieved, measures to restrict the movement of ICE vehicles in city centres or densely populated urban areas must be seriously considered. In this way, it is pertinent to mention that in a recent study conducted by Sustrans and the National Transport Authority (2020), it was determined that 58% of a sample surveyed in the Dublin Metropolitan Area stated that they would in fact be in support charging polluting vehicles more to enter Dublin city centre.

Intelligent transport systems (ITS) and behavioural change programmes also present useful tools in disseminating real time trip planning information and trip time estimations to travellers (advanced traveller information systems), and in adapting road traffic regulations to evolving real time conditions for safety and efficiency considerations to encourage modifications to trip characteristics e.g. variable/dynamic speed limits, variable messaging systems (Advanced Driver Assistance Systems). However, aside from the use of ITS in the operation of road user charging, the use of this technology in managing travel demand is limited, as to date, it has primarily functioned as a tool on information provision and decision support. For example, the NTA's Smarter Travel Workplace Programme resulted in a reduction of 18% for commute trips by car in the workplaces that participated in the scheme. Applications such as Mobility as a Service (MaaS) are useful in stimulating changes in modal choice and easing the decision-making process, by integrating various modes in one place, via the travel planning and integrated ticketing functionality of the service.

4.2.2. Demand Management Policy in Ireland

A series of national reports and strategic policy publications released in the past twenty years in Ireland. Table 13 shows, the use of demand management measures as tools to be considered to support a mode shift and reduce emissions from transport by complementing infrastructural elements of the strategies/plans. However, economic or fiscal instruments to a large extent have been spared at various implementation phases of such programmes, even though they have consistently formed central components of these policies. Many of the objectives set out in these documents make reference to a shifting of the onus to local authorities and city councils to review, and to decide upon and implement demand management measures in their areas. This is a positive action, as the effect of TDM interventions will ultimately be felt locally and thus, should be managed the same. For example, identifying appropriate measures for implementation in Cork city, of course, may not be suitable for introduction in Dun Laoghaire Rathdown, and vice-versa. Thus, specific localised knowledge is required in devising such methods of controlling travel demand, in this way leadership from local authorities is critical. The CAP and the Platform for Change documents are perhaps the most direct in their support for implementing demand management measures to support public transport and active mode infrastructure provision.

Table 13 Demand Management Actions, Targets and Objectives from National Reports and Strategic Publications

Policy/ Reports	Actions/ Targets/ Objectives			
Climate Action Plan (2019)	Better us of market mechanisms to support modal shift Consideration of how we can implement localised travel planning/ behavioural change information programme	Enhancing priority for public transport Consider further opportunities to expand and better integrate existing mobility management initiatives for institutions and enterprises such as Smarter Travel Workplaces, Smart Travel Campus, Green School Travel and Workplace Travel Plans, including the potential for increased participation by Local Authority-led structures	Develop a regulatory framework on low emission zones and parking pricing policies and provide local authorities with the power to restrict access to certain parts of a city or a town to zero-emission vehicles only. Examine the role of demand management measures in Irish cities, including low emission zones and parking pricing polices Giving Local Authorities more discretion in designating low emission zones	Development of an overall Park and Ride implementation plan including, where feasible, the provision of multimodal facilities A time to seek plan permissions and commence construction of car park extensions at rail stations and for new strategic park and ride sites
National Development Plan (2018)	Park and Ride Programme: strategic facilities at rail, Luas and bus locations, for example, Swords, Finglas, Dunboyne, Liffey Valley, Naas Road, Carrickmines, Woodbrook and Greystones	Consideration of the Cork North Ring Road could best be assessed as part of an overall transport strategy for the metropolitan Cork area which would include the examination of public transport and demand management options		
National Planning Framework (2018)	Enabling more effective traffic management within and around cities and re-allocation of inner-city road-space in favour of bus-based public transport services and walking/cycling facilities.	Expand attractive public transport alternatives to car transport to reduce congestion and emissions and enable the transport sector to cater for the demands associated with longer-term population and employment growth in a sustainable manner		
Smarter Travel (2009)	Actions to reduce distance travelled by private car and encourage smarter travel, including focusing population and employment growth predominantly in larger urban areas and the use of pricing mechanisms or fiscal measures to encourage behaviour change	Reduce the necessity to travel through the adoption of flexible working policies. Ensure that the public sector is an exemplar in the area of e-working and will require all organisations in the public sector to set targets to encourage e-working where appropriate. Implement a programme to promote Personalised Travel Plans (targeted marking and incentives) aimed at citizens in areas served by public transport	The Government has introduced a parking levy on employee car parking in key urban areas in the region of €200 per annum to dissuade use of the private car for commuting purposes. Work towards a requirement on organisations with over 100 staff to develop and implement workplace travel plans. Seek a plan from the OPW to reduce car-parking spaces a Government offices where alternative travel options are possible and require other public	In the context of the Commission on Taxation Report in 2009, consider the application of fiscal measures aimed at reducing car use and achieving a shift to alternative modes of transport, which will ease congestion, reduce further transport emissions and take into account economic competitiveness. Implement more radical bus priority and traffic management measures to improve the punctuality and reliability of bus services and to support more efficient use of bus fleets. They may involve making some urban street car-free.

			sector organisations to do likewise	
A Platform for Change (2001)	Top-down approach: the provision of the additional public transport infrastructure alone will not be sufficient, and some form of demand management for car trips is necessary to control highway congestion Given that the M50 is a duel 3-lane motorway, this would indicate that special demand management measures are required for the M50 and M1 motorways	A demand management strategy is a critical element of the DTO Strategy, and a comprehensive Demand Management Study is necessary to develop this	Develop demand management policy Implement demand management in step with improvements in public transport supply	

In the NTA Demand Management Report (2015), the recommendations for congestion charging, fuel duty and parking levies were to 'give further consideration to the potential benefits of introducing [such measures]'. However, it is clear in many European examples that the potential benefits of such interventions are widely recognised and understood. The European Political Strategy Centre (2016), stated that the best solution to tackling the outdoor air pollution is to firstly drive towards 'Low-Emission Mobility' which would involve modernising mobility and enact a complete systemic change. Tough and potentially unpopular decisions will need to be taken in order to re-think how transport is planned, from the mindset of the efficiency of transporting people rather than vehicles.

Overall, if a significant and sustainable reduction in carbon emissions produced from transport is to be realised in Ireland, the adoption of a selection of hard demand management measures is required. While an increase in investment for public transport and active mode infrastructure is essential in providing attractive alternatives to the private car and to cater for any additional demand, the marginal costs and externalities of using transport infrastructure (inclusive of roads) must also be sufficiently accounted for. Mechanisms such as road pricing (congestion charging, low emission zones), home working incentives, parking restraints and fuel pricing have all been demonstrated to be effective measures to encourage a mode shift and reduction in emissions via reducing traffic flow of private cars. These measures have been discussed at length in various strategic policy documentation in the past two decades with associated actions, yet there still exists a reluctance to physically limit the space available to private cars in urban areas and reallocate such space to sustainable modes.

International best practice for travel demand management implementation, some of which have been drawn on in this report, provide numerous examples and case studies of the impacts and lessons learned from introducing such measures. Thus, the rhetoric expressed from Irish authorities needing to review and 'give further consideration to the potential benefits' of such schemes should no longer be recognised as valid justification for inaction and lack of progress made at this stage. Proactive decision-making and support followed by actual implementation is required from key policymakers to enact the systematic change that is necessary for a just transition to low carbon transport.

4.2.3. Key Findings – Travel Demand Management Strategies

- Relative to European neighbours, Ireland critically lacks in the department of demand-oriented transport policy making and provision, which is something that will be required if growing trends in private car use are to be controlled in urban areas.
- While instruments that instigate behaviour change from an incentivisation approach are required and welcomed, they must be positioned alongside economic 'market-based' fiscal measures, in order for the objectives of travel demand management to be optimised.
- Parking restraint in respect to free parking at schools, colleges and workplaces is an issue that must be seriously considered by local authorities and central government, particularly in relation to the availability of parking for public and civil servants.
- International experience presents solid evidence supporting the success of hard fiscal measures in addressing congestion, emissions and air quality. Thus, as improvements are made to public transport supply the implementation of LEZs, congestion charging, parking restrictions, and car-free zones ought to be considered by local authorities in order to sufficiently control any growth in the demand for private car trips.

4.3. Park and Ride

Park and ride (PnR) has been a popular and, in many cases, a highly effective demand management measure to incentivise public transport use, address accessibility concerns, and intercept private car trips before they reach congested city centre areas. It is a commonly applied congestion mitigation tool to remove excess traffic flow from urban areas where existing high frequency and high capacity public transport infrastructure and services are available, and it may also act as an alternative to the provision of costly city centre parking. In Belfast, Translink provides over 2,600 parking spaces at rail and bus services (Translink, 2020). This policy of increasing PnR in Belfast was implemented to improve air quality and reduce congestion in the city (Belfast City Council, 2015; Northern Ireland: Environment Link, 2009). Reviews of the policy in the city have shown positive impacts and the demand with users has been high (Northern Ireland Assembly, 2014).

In relation to the environmental benefits associated with providing PnR sites, a study conducted in China, which examined the emissions savings made from introducing a PnR strategy in Shanghai found that 21.7 tonnes of CO, 1.2 tonnes of NO_x and 1.8 tonnes of hydrocarbon (HC) would be reduced for 250 working-days each year (Gan and Wang, 2013). This PnR scheme, 'Song-Hon Road P+R Lot', integrates with a frequent high capacity rail line and was the first implemented in mainland China. Research conducted in Tennessee, USA, which examined the impact of a pilot commuting programme incorporating the provision of PnR facilities to commuters determined that 44 PnR sites would potentially reduce daily vehicle kilometres travelled by 68% (Moore et al., 2019). In addition to this, it was found that energy usage was reduced by 92% due to the provision of PnR, and further reduced through the use of EVs by 42%. An extensive review examining the nature of PnR in Europe presented by Dijk and Montalvo (2011) found that out of 45 cities surveyed in Europe (inclusive of Belfast), 66% stated that PnR was of relevance and a solution to combat the negative environmental effects of private car use in cities. Interestingly, when questioned on which measures would be more effective than PnR from an environmental perspective, 54% of the cities surveyed said public transport, 31% stated a promotion of and facilities for cycling, while 31% believed that congestion charging or other forms of road pricing would be most effective (Dijk and Montalvo, 2011).

The attitudes and preferences of park and ride facilities is another popular topic examined in the literature. For example, experienced car users in a higher income cohort were found to be less likely to use PnR in Nanjing, China, whereas high levels of traffic congestion and urban parking charges would positively influence the likelihood of PnR facilities being used (He and He, 2012). The cost of PnR is perhaps one of the most sensitive attributes to PnR use and choice, which is supported by Seik (1997) who found, after surveying 122 PnR sites in Singapore, that trip cost was a statistically significant factor influencing the choice of PnR. A similar study in Perth, Australia determined that availability of paid parking bays, bike lockers and trip characteristics such as time of day and access mode were statistically significant in PnR use and station choice, more so than the access distance to the station (Olaru et al., 2014).

The introduction of PnR sites often forms part of larger regional or city level transport plans, in which PnR sites integrate with other sustainable mobility measures. This is noteworthy, given that, the success of PnR is normally attributable to adjacent policy or regulatory decisions such as the pricing of inner city on-street and private parking at its marginal cost or premium, as well as cheap, convenient and reliable public transport services. These complementary factors encourage the wider usage of PnR sites and similarly act as a prerequisite to their introduction as they are critical for their long-term viability (Dijk et al., 2013). However, there is a body of research which questions the effectiveness of park and ride and contests their potential in reducing traffic and vehicle kilometres travelled (vkt). Meek et al. (2011) and Parkhurst (1999; 1995) state that while the objective of PnR is to intercept car users who would normally travel door to door by car, in reality some PnR sites can induce demand for car trips for access. For example, individuals who would not normally use their car for any segments of their trip, may be attracted to drive to a P&R site, which as a result adds more vehicles to the road network. Parkhurst (1999) found that in three out of eight PnR sites examined in a study conducted in the UK, there was an increase in vehicle kilometres travelled as a result of PnR. The premise of this is that if the car access trip to the PnR site is longer than the public transport journey, then the likelihood of PnR simulating a reduction in traffic congestion is diminished (Olaru et al., 2014; Parkhurst, 2000). Furthermore, Noel (1988) delineated the situation in which falling levels of congestion could attract some car users back to their car to benefit from shorter travel times, which as a result increases the accessibility and attractiveness of driving (Dijk and Montalvo (2011). This may be perceived as a rebound effect to PnR, an extension to the 'Law of Demand' (Linn, 2013; Litman, 2001).

Thus, in the context of mitigating carbon emissions from transportation, it is suggested that several strategies of PnR should be seriously considered to offer a viable alternative to workplace parking in regional cities, which is a strong determinant of car use, particularly when it is offered to employees at no cost. PnR is a sound demand management measure for local authorities and city councils to adopt to encourage a shift to public transport services, and a reduction in congestion and emissions, which can potentially make available inner-city car parking for mixed use development or other repurposing for societal benefit, rather than solely for motorists. However, it must be reiterated that in order for PnR to successfully intercept sufficient numbers of private car trips before entering city centre areas, public transport capacity and frequency must be increased to cater for the additional demand placed on bus and rail services.

4.3.1. Key Findings – Park and Ride

- The success of park and ride is contingent on reliable, affordable, high frequency and high capacity bus and rail services. Thus, continued investment to sustain a high level of service of public transport services is paramount in this regard.
- A number of park and ride sites have been proposed under various regional city transport strategies, however, the uptake of these sites will depend on the successful implementation of BusConnects or the construction of new light rail lines and heavy rail stations.
- Alternative conceptual models of PnR, should be explored in the advent of BusConnects implementation across the country.
- More research is required to evaluate the impacts of providing park and ride facilities, such as their potential in reducing private car traffic and in-vehicle kilometres travelled, in addition to the emissions saving potential of PnR sites.
- Expansion of parking facilities at existing rail stations is welcomed to ensure that any increases in passenger demand for public transport services can be catered for from the perspective of ease of access and level of service.

5. Potential Mitigation Options

5.1 Mitigation Options and Research Findings

The options presented below are informed by the review of the literature, research conducted, and stakeholder engagements undertaken during this research. It should be noted that this list of options was arrived at prior to the current Fianna Fáil, Fine Gael and Green Party government came to power.

Option 1: Electric Mobility – Directed supports
International research and the analysis conducted by DPER show that the cost of meeting our emissions targets via EVs maybe prohibitive. The key variable in supporting EV subsidies is how long will they need to stay in place. The lack of certainty on when EVs will meet total cost parity with ICEV's, the costs in rolling out and maintaining charging infrastructure and the ability of the motor industry to produce the numbers of EVs required cast a shadow on the targets in the CAP.

If limited resources are available for financial supports for EV purchase – they should be targeted in an equitable way and should focus upon those with no sustainable travel alternative. More evidence is needed to estimate the wider economic benefits of these supports and this should be done prior to any longer-term commitment to EV subsidies.

Option 2: Electric Mobility – Expanding supports to non-car modes
Any financial supports for electric mobility should be extended beyond passenger cars and should similarly consider electric scooters and bikes. This would include and be supported by the legislation that would allow electric scooters to safely use our roads.

Option 3: Active Mobility – Integration with public transport
Cycling can play a vital role in extending the use and accessibility of our public transport networks by better facilitating first and last mile trips. Investment in secure cycle parking at our public transport hubs could facilitate multi modal trips and encourage a mode shift away from the private car as demonstrated in the reported case studies.

Option 4: Active Mobility – Sustained investment
Increases in cycling and walking do not happen overnight, they require sustained investment in education, safe and segregated infrastructure and promotion to be successful. Any financial resource that is dedicated to this mode of transport should be cognisant that it takes long-term commitment and political willingness to build a cycling culture and by starting now, significant emissions reductions could be realised by 2050.

Option 5: Active Mobility – Bike to work scheme
The bike to work scheme, launched in 2009, has remained largely unchanged since its introduction. The scheme has been very successful but at this stage we recommend that it be revisited, and modifications made with a particular focus on extending the scheme to third level students. Another suggestion would be to remove value added tax from the purchase of any bicycle (inclusive of e-bikes) or bicycle equipment in any reform on financial instruments for bicycle purchase.

Option 6: Public Transport – Investment
A shift towards public transport away from private cars is the key to achieving our emissions targets in the long run. While walking and cycling and other travel demand management policies will assist, the most sustainable way for people to move in a sparsely populated country like Ireland is by public transport. The recommendations of the 2017 Citizens Assembly on climate change related to investment in public transport versus private transport should be implemented. That is, all investment in transport should have a 2:1 ratio in favour of public transport.

For a number of decades there have been several large public transport projects that have been muted in Ireland. Political and economic cycles have meant that these projects have yet to come to fruition. An extensive number of business cases, cost benefit analysis and transport modeling have been conducted on these projects and in most cases their merits have been long since established. While the construction of any of these projects may not meet short term climate change goals, it is vital that when we look to our next set of more difficult targets in 2050, that these projects be fully operational. In the following section this option is split between rail and bus projects.

Option 7: Public Transport – Cleaner vehicles
The work that is on-going by the NTA in decarbonising our public transport fleet should continue and Ireland as a technology taker should examine closely international best practice on which vehicles and rolling stock should be invested in. Life Cycle cost analysis should be undertaken in conjunction with any decisions made on purchasing new public transport vehicles.

Option 8: Public Transport in Towns and Rural Areas – PSO
Evidence from an NTA initiative to redesign bus systems in large towns has shown success. The redesign of the bus system in Athlone has shown a 220% increase in passenger numbers in that town. Further research is required in this area to determine the benefits of this increase in PSO.

Option 9: Working from home – Supporting new work practices
During the COVID-19 pandemic Ireland endured a crash course in adapting to WFH. The research conducted to date in Ireland demonstrates that there is pent-up demand for the ability to WFH, and when the pandemic passes and travel restrictions are lifted further research needs to be conducted on WFH. However, the results presented in this document demonstrate the potential emission savings from a policy supporting WFH and innovative supports should be considered to facilitate this new work practice, such as a bike to work style scheme for home offices. It is envisaged that policies supporting WFH would come at a much lower cost per tonne of CO_2 abated then any of the policies recommended in this document.

Option 10: Travel Demand Management Strategies – Road user charging
Following the carrot and stick approach adopted in many other countries to facilitate the modal shift towards sustainable transport modes it is recommended, after sufficient capacity is added to our public transport networks, that we consider all options related to road user charging and TDM.

Option 11: Travel Demand Management Strategies – Workplace parking
The provision of free parking spaces at workplaces is undoubtedly a large contributor to the dominance of the private car nationally for commuting trips. A recommendation of the report

would be to further examine the potential of charging for these spaces to encourage the use of alternative modes of transport.

Option 12: Travel Demand Management Strategies – Low emission zones
Internationally, low emission zones (LEZ) have been shown to decrease carbon emissions and improve air quality. It is a recommendation of this report that consideration be given to introducing such zones in our larger urban areas. These zones would ban "dirty vehicles" entering the zones and this may have many potential outcomes. It would improve air quality but also act as a catalyst for consumers purchase and switch to EVs.

Option 13: Evaluation of projects – including carbon
Our current evaluation of transport projects does contain the estimation of emissions. However, this needs to be at the forefront of all evaluation of investment in transport - from subsidies for public transport services to large investments need to be ranked and evaluated using carbon reduction measures. Life-cycle analysis needs to be included in the evaluation of new options.

Option 14: Research funding
Ireland is one of the few countries in Europe that does not have a dedicated call for fundamental research in transport science. The other areas of emissions reductions, agriculture and energy have dedicated funding calls and respective funding bodies. Transport is an outlier and it is suggested that a funding mechanism be established for this area to determine and support the means of achieving targets in this transdisciplinary field.

The final two options (13 and 14) have not been evaluated in section 5.2. These options are challenging to evaluate and their benefits are linked to building a set of fundamental research and industry skills in Ireland.

5.2 Analysis of Mitigation options

Table 15 below provides a policy impact matrix of the mitigation measures discussed in this study. The approach used to guide policy making is that of a traffic light analysis, this grades options using a traffic light colouring system, which has been adopted by DTTAS in similar reports (DTTAS, 2019b).

In Table 15 the following colour codes are used:

Potential annual emissions savings: Green = considerable reduction in emissions, Amber = moderate reduction in emissions, Red = limited reduction in emissions.
Costs: Green = low cost (less than €100 million), Amber = moderate cost (€100million - €1 billion), Red = high cost (€1 billion plus)
Time scale to reach emissions savings: Green = Contributing towards the 2030 targets, Amber = Contributing towards the 2030 and 2040 targets, Red = Contributing towards the 2040 and 2050 targets.

The levels chosen in Table 15 were decided upon from experience, reference to national policy documents and the review of international literature presented in this document.

Table 15 Policy measures considered

Mitigation Option	Potential annual emissions savings	Cost	Time scale	Details
Option One: Electric Vehicles			Before 2030	CAP target of 840,000 vehicles by 2030 (assuming current subsidies are continued)
Option Two: Electric scooters & Bikes			Before 2030	Further research is needed
Option 3: Integrating cycling with public transport			Before 2030	Further research is needed
Option 4: Active Mobility – Sustained investment			2030 / 2040 targets	
Option 5: Active Mobility – Bike to work scheme			2030 / 2040 targets	Further research is needed
Option 6a: Public Transport – Investment – Rail projects			2030 / 2040 targets	Projects: MetroLink, DART and Luas expansion
Option 6b: Public Transport – Investment – Bus projects			Before 2030	Projects: BusConnects in Dublin |& regional cities
Option 7: Public Transport – Cleaner vehicles			Before 2030	Current commitments
Option 8: Public Transport in Towns and Rural			Before 2030	Pending a review of the efficiency of PSO funding
Option 9: Working from home – Supporting new remote work practices			Before 2030	Further research is needed
Option 10: Travel Demand Management Strategies – Road user charging			2030 / 2040 targets	Success depends upon option 6a & b being implemented
Option 11: Travel Demand Management Strategies – Workplace parking			2030 / 2040 targets	Success depends upon option 6a & 6b being implemented
Option 12: Travel Demand Management Strategies – Low emission zones			2030 / 2040 targets	Success depends upon option 6a & 6b being implemented

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APPENDIX I

CO2 emissions from transport in tonnes per inhabitant
Share of CO2 emissions from road in total CO2 emissions from transport

	2004		2005		2006		2007		2008		2009		2010		2011		2012		2013		2014	
	CO2	% road	CO2	% road	CO2	% road	CO2	% road	CO2	% road	CO2	% road	CO2	% road	CO2	% road	CO2	% road	CO2	% road	CO2	% road
Australia	3.9	89.7	3.9	89.2	3.9	87.6	4.0	86.2	4.0	85.2	3.9	84.5	4.0	85.0	4.0	84.7	4.0	84.7	4.0	84.3	3.9	84.3
Austria	2.9	97.3	3.0	97.3	2.8	96.7	2.8	96.8	2.7	96.1	2.6	96.7	2.7	97.3	2.6	97.0	2.6	97.0	2.7	96.3	2.6	96.7
China	0.3	73.8	0.3	75.4	0.3	75.4	0.4	76.0	0.4	79.5	0.4	79.2	0.4	79.6	0.5	81.2	0.5	81.4	0.6	81.0	0.6	80.9
Denmark	2.4	92.0	2.5	91.1	2.5	92.8	2.6	93.1	2.5	92.4	2.4	92.0	2.3	92.8	2.3	92.1	2.0	91.8	2.0	91.4	2.0	92.1
France	2.1	96.3	2.1	96.4	2.1	96.4	2.0	96.3	1.9	96.2	1.9	96.3	1.9	96.4	1.9	96.3	1.9	96.2	1.8	96.2	1.8	96.5
Germany	2.0	95.7	1.9	95.6	1.9	95.9	1.8	95.8	1.8	95.9	1.8	96.3	1.8	96.4	1.8	96.6	1.8	96.6	1.9	96.9	1.9	96.7
Ireland	2.9	97.5	3.0	97.5	3.2	97.1	3.3	97.3	3.0	97.4	2.7	97.6	2.5	97.7	2.3	97.9	2.3	97.9	2.3	97.9	2.4	98.2
Italy	2.1	94.5	2.1	94.4	2.1	94.3	2.1	94.4	2.0	94.0	1.9	94.6	1.8	94.6	1.8	94.5	1.7	94.5	1.7	94.3	1.7	94.7
Netherlands	2.1	97.3	2.1	97.2	2.2	97.1	2.1	96.8	2.1	96.8	2.0	96.7	2.0	96.4	2.0	96.3	1.9	96.5	1.9	96.2	1.7	96.4
New Zealand	3.3	86.7	3.3	87.1	3.3	87.6	3.3	89.1	3.3	89.1	3.2	89.5	3.1	89.9	3.1	89.1	3.1	90.3	3.1	90.7	3.1	90.6
Norway	2.8	74.1	2.8	74.1	2.9	74.3	3.0	73.8	2.9	73.9	2.8	73.3	2.9	73.9	2.8	72.7	2.7	71.1	2.7	73.6	2.7	75.5
Portugal	1.9	97.2	1.8	97.2	1.8	97.2	1.8	95.5	1.8	95.4	1.8	94.6	1.8	95.4	1.6	95.5	1.5	95.1	1.5	95.0	1.5	95.7
Spain	2.5	87.9	2.5	87.5	2.5	87.3	2.6	87.6	2.4	87.7	2.2	88.4	2.1	87.4	2.0	88.5	1.8	85.4	1.7	91.0	1.8	91.6
Sweden	2.5	94.6	2.5	95.0	2.5	95.4	2.5	94.6	2.4	95.9	2.3	96.0	2.3	95.1	2.2	95.8	2.1	96.4	2.0	97.4	2.1	97.4
United Kingdom	2.1	93.8	2.1	93.4	2.1	92.5	2.1	93.0	2.0	94.1	1.9	94.2	1.9	94.2	1.8	94.2	1.8	94.3	1.8	94.0	1.8	94.3
United States	6.1	85.5	6.1	85.2	6.1	85.4	6.0	85.5	5.6	86.1	5.3	86.6	5.4	86.7	5.3	85.8	5.4	84.8	5.3	85.0	5.4	85.0

APPENDIX II

In order to estimate emissions saved from WFH a number of assumptions had to be made. While the approach taken does not proport to be fully accurate, it provides a reasonable estimation of the emissions saved.

In order to estimate emissions, the following are required.

- Mode of transport used
- Distance travelled
- Fuel type
- Amount of travel
- Emissions factor per km travelled

National averages were used in this estimation as it was not possible to locate the employees used from the data sources used in this analysis. Table AII 1 below details the sources used.

Table AII 1 WFH Estimation Values

Mode of transport used*	**Breakdown or emissions factor**	**Source**
Car alone	43%	CSO (2016) Census of Population 2016 – Profile 6 Commuting in Ireland
Passenger	20%	
Rail	3%	
Bus	11%	
Distance travelled	15km (30km – return trip)	CSO: https://www.cso.ie/en/releasesandpublications/ep/p-cp6ci/p6cii/p6td/
Amount of travel**		
One day a week	44 days	N/A
Two days a week	88 days	
Percentage of private vehicles by fuel type***		DTTAS (2018) Irish Bulletin of vehicle and driver statistics
Petrol	44%	
Diesel	56%	
Emissions factors (car) 2020 values		
Petrol (Urban)	148.271 (CO_2 per km)	DTTAS (2016) Common Appraisal Framework for Transport Projects and Programmes
Petrol (Rural)	121.377 (CO_2 per km)	
Petrol (Motorway)	133.940 (CO_2 per km)	
Diesel (Urban)	150.053g (CO_2 per km)	
Diesel (Rural)	113.937g (CO_2 per km)	
Diesel (Motorway)	121.545g (CO_2 per km)	
Breakdown of driving areas		
Urban	30%	Dey, S., Caulfield, B., Ghosh, B. Modelling uncertainty of vehicular emissions inventory: A case study of Ireland, Journal of Cleaner Production, 213, 2019, p1115-1126
Rural	50%	
Motorway	20%	
Emissions factors Public Transport		Walsh, C., Jakeman, P., Moles, R., O'Regan, B. A comparison of carbon dioxide emissions associated with motorised transport modes and cycling in Ireland. Transportation Research Part D: Transport and Environment Volume 13, Issue 6August 2008 Pages 392-399
Bus	15g (CO_2 per km per passenger)	
Rail	64 g (CO_2 per km per passenger)	

*Walking and cycling not considered as carbon neutral
**Working year is assumed to be 220 days a year
*** Does not consider other fuel types

The emissions saved were estimated by breaking down each group of workers and assuming the modal split shown in the table above. An emissions factor per km driven was then estimated for each of the drive modes. Drive alone was assumed to have the full amount of emissions whereas passengers were assumed to have half of the missions. Emissions factors for bus and rail were also used.

Distance travelled was then multiplied by the emissions factor to get a daily emissions value and then multiplied by the number of days in the policy scenario.