CRUSE to Safe Cycling in Ireland

An Open Source Methodology to Support Active Travel

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Under the EU Road infrastructure safety management (RISM) directive, the National Road Safety Strategy (RSS), and the Climate Action Plan Transport Infrastructure Ireland (TII) has a remit for road safety and decarbonizing a predominantly road-based network in Ireland.

To address data needs for both safety, business case development and project evaluation on the National Road Network (NRN), the Cycle Route Uptake and Scenario Estimation (CRUSE) Tool was developed. Cycling in Ireland represents only 3% of total modal share as of the latest Census (2016), but accounts for 20% of serious injuries and 7% of all fatalities. High resolution datasets on baseline and potential cycling levels are needed to meet Ireland’s climate and safety targets.

Due to an absence of reliable data, particularly rural cycling levels, TII commissioned the Institute for Transport Studies (ITS) at the University of Leeds and AECOM to develop a new tool for this purpose. ITS Leeds led the development of the PCT for England and Wales, which has “revolutionized the practice of strategic cycle planning nationally”. The tool is an open-source approach using recognized open-source methodology to enable planners, engineers, and other stakeholders to make evidence-based decisions for the NRN. CRUSE is available at <https://cruse.bike/> and builds on the Propensity to Cycle Tool (PCT) for England and Wales. CRUSE goes beyond the PCT in several important ways, modeling denser networks at higher levels of geographic resolution and additional purposes, including simulated recreational, social, shopping and personal trips, in addition trips to work and primary, secondary and tertiary education locations. The tool provides key ‘denominator’ information to enable reporting of collision rates per billion km cycled.

CRUSE is structured in a similar way to the traditional four-stage transport model, but its use of Open Street Map (OSM) data, used by [Cyclestreets.net](https://www.cyclestreets.net/) for routing, enables network quality to be assessed without costly surveys to record new infrastructure. OSM tags generate “cycle friendliness” estimates of all links on the network, based on existing recorded infrastructure. Many networks are provided, highlighting routes for directness (Fastest) and “cycle friendliness” (Quietest). It uses origin and destination data from the 2016 Census in combination with modeled demand data to estimate current and potential future cycling levels at area, route, and network levels for each county in Ireland.

For investment in cycling to deliver on the huge potential benefits, cycling must become safer. With growth in the E-bike market, the tool will help inform inter-urban and rural networks to support the transfer of trips to sustainable modes for longer journeys. The findings and resulting tool are directly relevant to addressing the challenges and opportunities faced by National Road Authorities (NRAs) across Ireland. The provision of open access evidence, that can be used non-experts and professionals, is relevant to countries with sustainable transport policies worldwide.

# 1. Introduction

Mobility kills. High energy transport systems are a major contributor to climate change, a leading cause of premature death and injury due to road traffic collisions, and a cause of disease due to airborne pollutants. Conversely, evidence-based and effective transport *policies* have great potential to decarbonize economies, improve public health, and save lives.

Transport is responsible for 23% of global greenhouse gas emissions, 70% of which are from road transport, nearly half of which (around 10% of global emissions) is from passenger cars (Jaramillo et al., 2022). The transport system encourages, enables and in some cases enforces unsustainable lifestyles. Services that are only accessible by car lock-in car dependency (Gray et al., 2001; Motte-baumvol et al., 2010; Shergold et al., 2012).

Recognizing the growing evidence of such impacts of poorly designed and performing transport systems, governments in many countries have set targets and taken actions. In the context of climate, road safety and physicial inactivity crises, policies to improve transport systems can be classified according to the ‘Avoid-Shift-Improve’ (ASI) framework (Jaramillo et al., 2022). The framework highlights the importance of demand reduction (*avoid*ing unnecessary trips), in addition to mode *shift* to sustainable modes and *improvement* of existing energy converters, in that order.

Uptake of cycling, the main topic of this paper, should be seen in this broader context of transport decarbonisation (Brand et al., 2020) and sustainable mobility (Burns, 2013). Although cycling uptake appears on the surface to only relate to the ‘shift’ part of the ASI framework, closer consideration of the knock-on impacts of cycling uptake shows that it can also help avoid unnecessary trips (Nello-Deakin, 2020). Furthermore, highly efficient e-bikes — which are seeing rapid uptake in Ireland and other countries — outperform electric cars, which are too heavy and expensive. Over-reliance on electric cars could slow the transition away from car dependency and inadvertently enable “high travel lock-in” (Anable & Goodwin, 2019). At the European level, the European Union has a target of reducing greenhouse gas emissions by 55% by 2030, compared to 1990 levels, and to achieve ‘net-zero’ by 2050.[[1]](#footnote-22)

Regarding road traffic casualties, another deadly consequence of inefficient transport systems, the Road Infrastructure Safety Management (RISM) directive (2008/96/EC) requires member states to implement a road safety management system (RSMS) for all public roads. Specifically, “Member States shall ensure that the ranking of high accident concentration sections and the network safety ranking are carried out”.[[2]](#footnote-23) Given that ‘safety’ in this context is usefully quantified as the number of people killed and seriously injured (KSI) per distance travelled, the directive requires estimation of distance travelled by mode, down to the road link level. For active modes, about which there is a paucity of data compared with motorized modes, this is a major challenge. Better data to inform road safety policies and interventions is a motivation for the CRUSE Tool outlined in this paper, and modeling active travel more broadly.

In Ireland, the Road Safety Authority (RSA) has set the target of halving the number of road traffic deaths and serious injuries by 2030.[[3]](#footnote-24) Doing so while simultaneously enabling rapid uptake of active modes will require key active travel routes to be identified and improved.

A proactive approach to the development of cycling policy and infrastructure is taking place in Ireland. The main frameworks underpinning these efforts are the Climate Action Plan[[4]](#footnote-26), the National Development Plan[[5]](#footnote-28), and the National Roads 2040 strategy[[6]](#footnote-29). These policy frameworks are backed-up by public support for active travel interventions: while only 3% of trips in Ireland are made by cycling according to the latest Census data from 2016,[[7]](#footnote-30) “83% of respondents supported enhanced walking and cycling facilities”.

At the regional level, the recently published Greater Dublin Area Transport Strategy[[8]](#footnote-31) reinforces these findings: “nearly a quarter of adults cycle at least once a week in the Dublin Metropolitan Area” with cycling in the Dublin area taking up to 60,000 cars off the road today. Extrapolating this on a per population basis across Ireland, with around 40% of the population living in Dublin, this suggests that around 150,000 cars could be removed nationwide just by achieving Dublin levels of cycling in all counties (notwithstanding existing cycling trips and differences in trip distances). 7 in 10 trips in Ireland are by car[[9]](#footnote-33). Cycling has the potential to replace a large proportion of these trips: “A high priority must also be given to cyclists, because trips by this mode have the potential to replace trips by private car, most specifically for short to medium distance trips, but increasingly for longer trips as e-bikes extend the range of this mode”[[10]](#footnote-34).

Further evidence of the importance of cycling in Ireland *already* is provided by the National Strategic Objective (NSO) from the National Development Plan, with €8.6 billion allocated to sustainable transport infrastructure including public transport and active travel interventions. Cycle infrastructure will be developed in synchrony with the BusConnects project, an entire redesign of the bus network in Dublin and Cork.

It was in this context that Transport Infrastructure Ireland (TII) commissioned the Cycle Route Uptake and Scenario Estimation (CRUSE) project. Based on the Propensity to Cycle Tool (PCT) for England and Wales, the CRUSE Tool was developed to provide evidence on current cycling levels and future cycling potential nationwide across Ireland.

A key consideration for TII is to ensure both urban and rural Ireland were targeted for cycling infrastructure, as shown in [Figure 1](#fig-dublin). To this end, TII extensively reviewed activity on Irish Roads and how the road network was being used by commuters, cyclists, heavy goods vehicles and other road users across the Irish transport network. The aim was for the tool to provide strong, national, systematic but locally-specific evidence to monitor cycling friendliness and safety in Ireland, to ensure strategic alignment with national, regional and local policies. The open source and publicly available nature of the tool ensures more inclusive and evidence-based conversations around cycle network planning between all stakeholders in the transport planning process. Other use cases in the Irish context includes monitoring the need for existing cycling infrastructure upgrades, undertaking appraisal for business case development, as well as safety and exposure information. The latter is in line with the European Cycling Federation, Dutch Cycling Embassy recommendations and the European RISM Directive, for reporting collision rates of vulnerable road users by 2024. These factors mean that the tool can be seen as an open access ‘leverage point’ in the planning system (Lovelace et al., 2020).

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| Figure 1: Illustration of the density of route networks generated by the CRUSE Tool for Dublin City and surroundings (top) and rural County Mayo on the West coast of Ireland. Source: CRUSE Tool, available at <https://cruse.bike/>. |

The rest of paper is structured as follows. In [Section 2](#sec-methods), we outline the methods used to generate the evidence presented in the CRUSE Tool for Ireland. In [Section 3](#sec-results), we present the results of the CRUSE Tool, including estimates of current cycling levels and future cycling potential at the national, regional and local levels. In [Section 4](#sec-discussion), we discuss the implications of the results for policy and practice. In [Section 5](#sec-conclusions), we conclude the paper.

# 2. Methods and data

The methods used to generate the evidence presented in the CRUSE Tool for Ireland build on the Propensity to Cycle Tool (PCT), which was originally funded by the UK’s Department for Transport and developed by a multi-university team. An important feature of the PCT is that it is open source and publicly available (at [www.pct.bike](https://www.pct.bike/)), allowing its use by all stakeholders in the transport planning process (Lovelace et al., 2017). The PCT approach has had major policy impacts, as outlined in Research Excellence Framework (REF) impact case studies, which demonstrate that the tool “revolutionised strategic cycle planning in England and Wales”[[11]](#footnote-44) by overcoming the barriers to cycling investment imposed by lack of evidence on cycling potential[[12]](#footnote-46) .

The first version of the PCT was based on current and future potential uptake of cycling for single stage *travel to work* at desire line, zone, route, and route network levels (Lovelace, 2016). It was launched in April 2017 as the government-endorsed tool for strategic cycle network planning, as part of the Cycling and Walking Investment Strategy (*Cycling and Walking Investment Strategy*, 2017). Extensions of the PCT approach have included estimation of benefits at the individual level (Woodcock et al., 2018), addition of travel to school network (Goodman et al., 2019), and improved modelling of impacts on health, environmental and distributional outcomes (Woodcock et al., 2021). Initially developed just for England, the PCT was extended to cover all of Wales (for commuter data only) in 2018.

The PCT approach has been applied in other countries, including Ireland (the topic of this paper), Scotland, and Portugal. In Portugal the ‘biclaR’ project, based on methods underlying the PCT, has been developed and deployed for the Lisbon metro region. The resulting evidence is available in an interactive web application hosted at [biclar.tmlmobilidade.pt](https://biclar.tmlmobilidade.pt) (Félix et al., 2022). biclaR includes estimates of impacts, using the World Health Organisation (WHO) ‘HEAT for Cycling’ tool[[13]](#footnote-49) and an ‘intermodality’ scenario that combines cycling with currently available public transit options based on General Transit Feed Specification (GTFS) data.

The CRUSE Tool seeks to overcome the following methodological limitations of the original PCT:

* Low resolution of data, with routes starting and ending in administrative zone centroids
* Limited coverage of trip purposes beyond travel to work and school
* A web interface that was not user-friendly or intuitive

Methods were developed to overcome each of these, as outlined in [Section 2.2](#sec-trip-purposes) to [Section 2.3](#sec-ui).

## 2.1 Disaggregation of origin-destination data

A feature of active travel interventions is that they require dense networks of routes to be effective (Parkin, 2018). This means that high levels of geographic resolution are needed in the data used to estimate cycling potential. However, datasets on travel patterns are often only available at the level of administrative zones. The Central Statistics Office (CSO) in Ireland provides Place of Work, School or College Census of Anonymised Records ([POWSCAR](https://www.cso.ie/en/census/census2016reports/powscar/)) data on the number of people travelling to work and school at the Electoral Division (ED) level, for example.

The method used to convert OD data to route networks used in the PCT was to calculate a single route between the population weighted centroids associated with each OD pair. This method works fine when the OD data represents movement between small areas, but was not appropriate for generating route networks from the POWSCAR data because zone centroids are so far apart that the resulting route networks would be sparse and unrealistic. To tackle this issue we developed a new method for OD data disaggregation called ‘jittering’ (Lovelace et al., 2022). The method works by first disaggregating the OD data based on a ‘disaggregation threshold’ and then assigning each disaggregated ‘sub-OD’ pair to ‘subpoints’ within each zone. As shown in [Figure 1](#fig-dublin), the resulting route networks are dense, even in rural areas.

## 2.2 Additional trip purposes

A limitation of the original PCT was that it only included travel to work data. This was partially addressed by the inclusion of travel to school based on data from the Department for Education in England (Goodman et al., 2019). An advantage of the POWSCAR OD data over OD datasets derived from census surveys in many countries is that it includes travel to school data. We commissioned a version of POWSCAR that included a breakdown of the total flows between OD pairs by purpose and mode, enabling a more realistic estimation of the ‘Baseline’ cycling network.

However, travel to school and work only constitute around only 30% of all trips in Ireland. To overcome this issue, we developed a spatial interaction modelling methodology to estimate the number of trips between each OD pair for additional trip purposes. The classification of trip purposes used in the CRUSE Tool was guided mainly by the trip purpose classification found within the National Household Travel Survey (NHTS), but with the addition of categories based on the comprehensive POWSCAR data, and the need to include recreational trips and multi-stage trips (not yet implemented). An overview of the trip purposes used in CRUSE is presented in [Figure 2](#fig-trip-purposes).

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| Figure 2: Trip purposes used in the CRUSE Tool. |

## 2.3 User interface

The CRUSE web application is statically hosted, meaning that it can be accessed without the need for a server running software such as the R package ‘shiny’ or Python packages such as ‘streamlit’ or ‘flask’ in the background (Wickham, 2021). Typical intended user stories are illustrated in [Figure 3](#fig-user-stories), which shows that the tool is designed to be used by both professional and non-professional users. For the main target audience, professional transport planners working at the county level, the tool provides a range of outputs, including estimates of cycling potential at the county and network level. The provision of balanced (the default), quietest and fastest route networks enables planners to consider the trade-offs between directness and ‘cycle friendliness’ when planning new infrastructure. The tool also provides data downloads, enabling estimates of cycling potential on the network to be visualised and analysed with other tools such as QGIS, Python or R.

For non-professional users, the tool provides a simple interface to explore the cycling potential of the network. By providing a single landing page that is suitable for both professional and non-professional users (such as an advocate or parent interested in safe routes to school), the tool aims to facilitate communication between these groups.

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| Figure 3: Hypothetical user stories for the CRUSE Tool illustrating that it can be used in different ways by different user groups. |

# 3. Results

The main result of the CRUSE project is an open access web application and datasets on current and potential future cycling levels in Ireland, with evidence provided at county and route segment levels. Like the PCT on which CRUSE builds, a key feature of the results is that they are systematic and available for all counties, and most routes on which cycling is permitted, in Ireland. The full set of results are therefore too extensive to present in their entirety in this paper. Through the interactive web application, users can explore the data to generate the results that are most relevant to their needs, whether that is finding the cycling potential on a particular road or finding ‘weak links’ or barriers in the cycle network associated with a particular school, work place or other destination.

Instead of trying to show such use cases, of which there are many hundreds, we present a selection of results to illustrate the main features of the CRUSE Tool.

To illustrate the results in urban areas, we took the top 4 cities in Ireland by population: Dublin City, Cork, Limerick and Galway (with city populations of 0.6, 0.2, 0.1 and 0.1 million respectively). The results for central areas demarcated with circular areas with a radius of 3km for these cities are presented in [Figure 4](#fig-city-results).

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| Figure 4: Fastest, balanced and quietest cycle networks within 3km circular areas containing the four largest cities in Ireland. The networks are coloured by cycle friendliness and with widths varying in proportion to the potential level of cycling under the ‘Go Dutch’ scenario. |

Aside from the widely varying sizes and route networks of each city, with Dublin having by far the densest network, it is clear from the visualisation of cycling friendliness that there is a lot of room for improvement in all cities. Dublin has had received most investment in cycling infrastructure and this is apparent from the high proportion of the route network that is green, even in the ‘Fastest’ route network representing routes that prioritise speed and directness over comfort and safety. Dublin also has the highest mode share of cycling of the four cities, adding to the evidence base showing that investment in cycling infrastructure is effective in increasing cycling uptake.

Although Dublin City has made progress, there are still many parts of the Fastest route network, and even some parts of the Balanced and Quietest route networks, that are not cycle friendly and which have high cycling potential. According to a recent report, 71% of residents in the Dublin Metropolitan Area support “more cycle tracks along roads, physically separated from traffic and pedestrians”.[[14]](#footnote-68) The results for the Dublin area could help prioritise investment in cycling infrastructure in the city.

# 4. Discussion

The CRUSE Tool provides evidence on current and potential future cycling levels across Ireland down to the street level, with potential assigned to ‘fastest’, ‘balanced’ and ‘quietest’ route networks. This provision of multiple scenarios of behaviour changes *and* multiple scenarios of investment, for example in cycling infrastructure next to major roads vs quiet residential streets, is a key feature of the CRUSE Tool.

As highlighted in a paper on cycling infrastructure preferences based on a case study of Dublin, both directness and quietness are important (Caulfield et al., 2012):

Direct routes with short journey times were found to be the most important positive variable for existing cyclists and non-cyclists in determining route choice. This is followed by infrastructure type, the number of junctions along the route, traffic speed and cyclist volumes. In terms if infrastructure, regardless of the level of cycling confidence, routes which have ‘no facilities’ or ‘bus/cycle lanes’ are the least favoured cycle route types.

The CRUSE Tool can help both in terms of describing the current situation, and also prioritise investment in those direct routes with high cycling potential that lack adequate cycling infrastructure, highlighted by Caulfield et al. (2012). It will also support reporting for the RISM Directive on road casualties as part of the road safety management system.

While the CRUSE Tool is not the first national and publicly available tool for cycling planning, it has some unique features that make it relevant for other countries, and other national road authorities tasked with making their transport systems safe.

TODO: outline these features.

The CRUSE Tool is designed to be used by a wide range of stakeholders, including transport planners, engineers, and other professionals, as well as non-professionals.

# 5. Conclusions

# 6. List of abbreviations

CSO: Central Statistics Office

CRUSE: Cycle Route Uptake and Scenario Estimation

ED: Electoral Division

GTFS: General Transit Feed Specification

KSI: Killed and Seriously Injured

NRA: National Road Authority

NRN: National Road Network

OD: Origin-Destination, typically referring to origin-destination data which contains information on the number of people travelling between each pair of zones

OSM: Open Street Map

PCT: Propensity to Cycle Tool

POWSCAR: Place of Work, School or College Census of Anonymised Records

TII: Transport Infrastructure Ireland

# 7. Declarations

## Availability of data and material

Data was obtained from the Central Statistics Office (CSO) and Transport Infrastructure Ireland (TII) under license and cannot be shared publicly. The code used to generate the results presented in this paper is available at https://github.com/cruse-bike.

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## Competing interests

The authors declare that they have no competing interests.

## Authors’ contributions

RL led the development of the CRUSE Tool, with input from JT, EV, HM, EB, PW, GOT, DB, and SM. SM instigated the project and coordinated its policy impact. PW, EB and GOT provided project management and transport engineering expertise.

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