Appendix B   Methodological Approach

This section sets out the methodology which was utilised in the production of this analysis. It is informed by international literature and knowledge of the Irish transport network and Irish travel patterns. It is envisaged that this methodology will be transferable to later studies of congestion in Ireland's regional cities.

B.1   Project Management

This report was completed by the Department of Transport, Tourism and Sport's Economic and Financial Unit (EFEU) in conjunction with a number of agencies. A consultative group was assembled with representatives from the Department, the National Transport Authority (NTA), Transport Infrastructure Ireland (TII) and Dublin City Council (DCC).

B.2   The NTA's ERM Transport Model

The analysis undertaken in this process was conducted using the Eastern Regional Transport Model (ERM) which is managed and operated by the NTA. The model is a strategic multi-modal, network based transport model covering the Greater Dublin Area (i.e. the counties of Dublin, Meath, Kildare and Wicklow). It is one of 5 regional transport models employed by the NTA.

The model includes all of the main surface modes of travel (including travel by car, bus, rail, heavy goods vehicles, walking and cycling). The model currently comprises a morning peak model covering the three hour period between 07:00 and 10:00, an afternoon inter-peak model covering the single hour between 14:00 and 15:00 and an evening peak model between 16:00 and 19:00. The model was first developed in 1991 as part of the Dublin Transportation Initiative (DTI) study.

The Dublin Transportation Office (DTO) took ownership of the model after it was established in 1996, and was given the remit to maintain and regularly update the model and make it accessible to DTO agencies and third parties on request. It undertook a number of updates of the model. The latest update of the DTO's transport model was started in early 2008 and was completed in late 2009. Following this, the DTO was subsumed into the National Transport Authority (NTA) which was established in December 2009. The GDA transport model is now owned by the NTA, which is the authority responsible for its maintenance and

use. As of end-2015, the NTA have completed work to establish an updated transport model for the GDA as well as individual models for each of the regional cities. The key attributes of the model are as follows:

- Full geographic coverage of the region;
- A detailed representation of the road network, including the impact of congestion on on-street public transport services and modelling of residents' car trips by time period from origin to destination;
- A detailed representation of the public transport network and services – it can predict demand on the different public transport services within the region;
- A representation of all major transport modes including active modes (walking and cycling) including accurate mode-choice modelling of residents;
- A detailed representation of travel demand. by journey purpose, car ownership/availability, mode of travel, person types, user classes & socio-economic classes, and representation of four time periods (AM, Inter-Peak, PM and Off-Peak); and
- A prediction of changes in trip destination in response to changing traffic conditions, transport provision and/or policy

The ERM Transport Model covers the full Greater Dublin Area (GDA) and also includes zoning and transport network coding for Co. Louth. The model runs on a zoning system and contains 1680 zones with 491 in Dublin City Council, 253 in Fingal County Council, 221 in South Dublin County Council, 175 in Dún Laoghaire-Rathdown County Council, 142 in Kildare County, 138 in Meath County and 103 in Wicklow County. In addition there are 103 zones external to the GDA and 3 special zones around Dublin Airport, Dublin Port Terminal and Dún Laoghaire Ferry Terminal. In the metropolitan area, the zones are subsets of the District Electoral Divisions (DED's) used to compile Census data. In the hinterland area, zones are

Figure 12: ERM Zone System
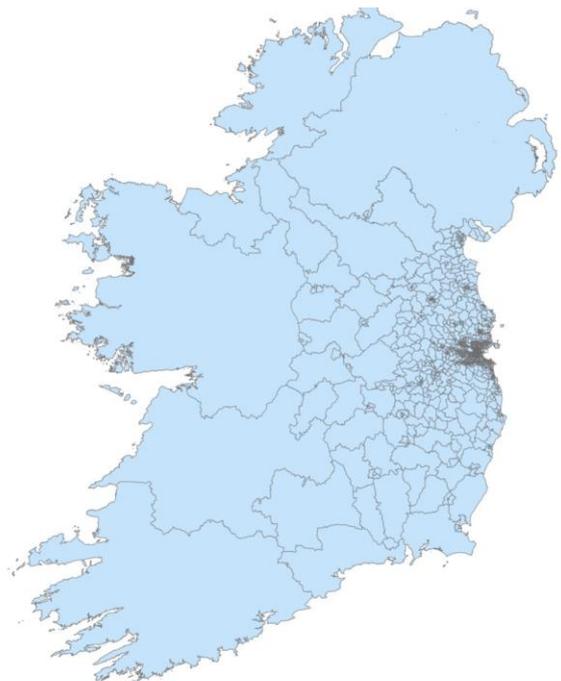
much larger and are an amalgamation of DED's.

*Figure 13: Greater Dublin Area Boundary*

Five separate periods of the day are modelled. The am-peak model covers the three-hour period from 07:00 to 10:00. The Morning Inter-Peak covers the period between 10am and 1pm and the Afternoon Inter-Peak covers 1pm to 4pm. The PM Peak period is from 4pm to 7pm and the Off-Peak Period is 7pm to 7am. For the purposes of this study the AM-Peak, Inter-Peak and PM Peak models were utilised.

Appendix B   The base year for the model is 2012 with the nominal month of April. This is largely driven by the date of the Census (POWSCAR) and the National Household Travel Survey (NHTS). It should be noted that the POWSCAR dates to 2011 but the travel patterns are assumed to be broadly the same in 2012. Travel demand is broken down by six journey purposes: Work (commuting); Education; Employer's Business; Shopping; Other; and Non Home Based. Travel demand is further segmented by two person types – i.e. those with a car available for their trip and those without a car available for their trip.

In terms of structure, the model follows the classic 4-stage transport model (trip generation, trip distribution, mode split and traffic assignment) and incorporates an additional stage called hour of travel choice. This is used to model the impacts of peak spreading where people decide to depart at an earlier (or later) time to avoid congestion or crowding during the morning peak. The structure of the am-peak model is shown in Figure B.1 below. In practice, though the different model components are run in the sequence shown, they are not run in isolation from each other. In particular, the model includes an iterative feedback loop between the mode choice, hour of travel choice and route choice stages. Iteration proceeds until equilibrium is achieved across travel modes, hour of travel and route choice.

Figure B.1: Structure of AM-Peak Model
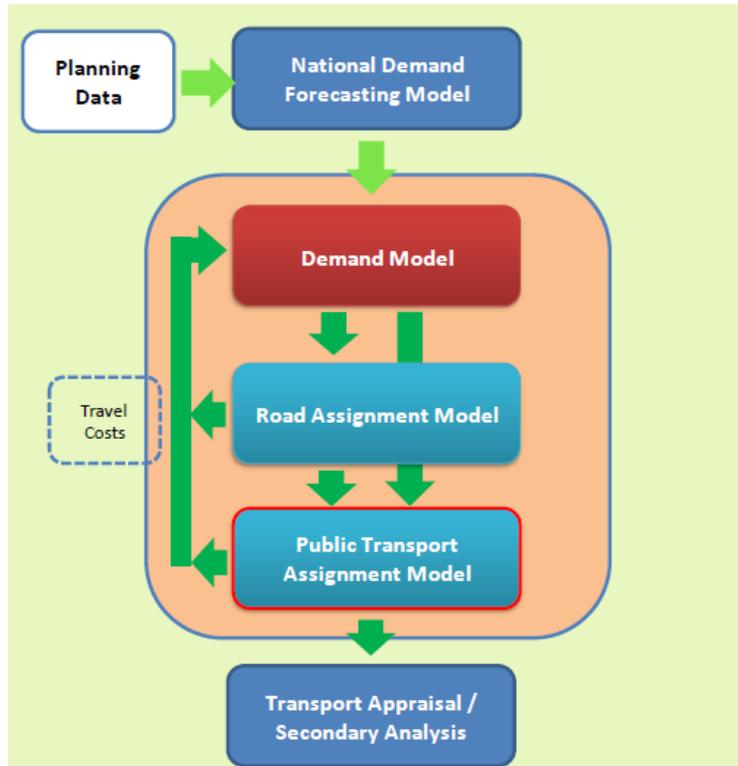
The model utilises data from a variety of sources including Census travel to work data, NTA GDA travel surveys, car ownership data and CSO small area population statistics to estimate activity and operation on the network. By going through the steps outlined in Figure B.1, trips are assigned on the network such that an observation of current network conditions is made. From this, much analysis can be done in terms of future forecasting and the effect of changes to the network. The model is used for appraisal of new transport infrastructure, general transport planning and policy research.

B.3 Analytical Approach

The methodological approach employed in this research paper is informed by international literature described in Appendix A and the transport modelling tools available in the GDA. In particular it is similar in nature to that employed by Wallis and Lupton (2013) for the New Zealand Transport Agency.

No obviously superior single approach has been established in the literature to assess the cost of congestion. Rather there are a myriad of definitions and approaches. In terms of

carrying out the actual measurement of congestion costs there are two primary identified types of approach[1] as highlighted in Appendix A. The approach taken in this report follows an engineering approach in the measurement of congestion. As such, it focuses on Volume over Capacity on roads as the measurement mechanism and is similar to the approach to that undertaken by the NZTA. Each scenario is based on a volume over capacity ratio. As such, the model is run based on current traffic data. The scenarios are then implemented by capping the properties of each link to the scenario if it is above the assigned capacity level. A process of an analysis was undertaken to define each of the scenarios based on the international literature and the operation of the GDA's transport network and this will be detailed in the following section.

B.4 When Does a Road Become Congested?

As we have discussed there are a variety of definitions employed in the international literature. The following details how these definitions of aggravated congestion could be analysed using an engineering approach to measurement.

One definition would be to compare the current level of congestion and operation to free flow conditions to assess the extent of delay. This is done by comparing the level of delay to that experienced during free flow conditions and is akin to the previously detailed economic definition of congestion. An opposite definition of congestion would be to take a strictly engineering definition whereby congestion occurs when a road's capacity is exceeded. Under this scenario one would assess anything beyond full flow capacity as representing congestion. As highlighted in Appendix A, there are issues with using these definitions.

A third definition which can be utilised sits between that identified under the economic and engineering theories. Instead of focusing solely on user impacts or infrastructural capacities the approach focuses on somewhat of a balance between the two distinct definitions. While also imperfect given the lack of definitive definition, it represents what EFEU believe to be a relevant, realistic and robust estimation of congestion costs in the context of the GDA's transport network. The following analysis provides further detail on these definitions.

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[1] Within each option type there are a variety of sub options but these are summarised into two types.

Figure B.2 presents a generalisation of the relationship between the volume over capacity ratio and the speed on a road link in the GDA[2]. The three comparative scenarios can easily be mapped to this graph. The economic definition in its purest form would assign congestion as being any point beyond which the volume over capacity ratio is zero or free flow. A purely engineering definition would see congestion as being any point beyond the 100% volume over capacity ratio.

As figure B.2 shows, when traffic volumes reach around 80% of a road's optimum capacity, speeds begin to sharply decrease, which is when significant negative impacts begin to arise. Therefore, for the purposes of this study, we assume that, above 80% capacity, the costs of additional traffic on a road begin to exceed the benefits. So, 'aggravated congestion' has been measured as the difference between observed total journey times and those journey times that would have been observed if the road were operating at 80% of its optimum capacity.

Figure B.2: Plot of Link Speed vs. VoC
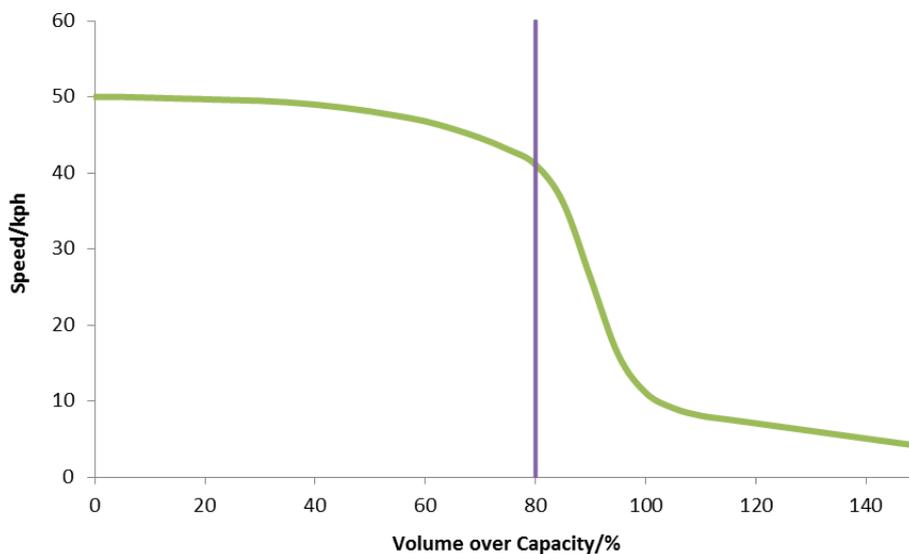
A second method of judging the efficiency of a link is to plot the journey time on the link against traffic volume – this plot is shown in Figure B.3 below. Both curves show that link delays begin to increase substantially just prior to the stage where traffic volumes reach the link's physical capacity. The graphs also show that when traffic volumes are at (circa) 80% of capacity, the link is relatively free from congestion and hence traffic speeds and travel times

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[2] Figure is illustrative only and is based on data from a number of links from a previous version of the ERM model.

are relatively constant. These two figures demonstrate the variance between the chosen scenarios and the importance of defining congestion. This overall relationship was also observed in a separate validation exercise using M50 data.

Figure B.3: Plot of Link Travel Time vs. Link Traffic Volume
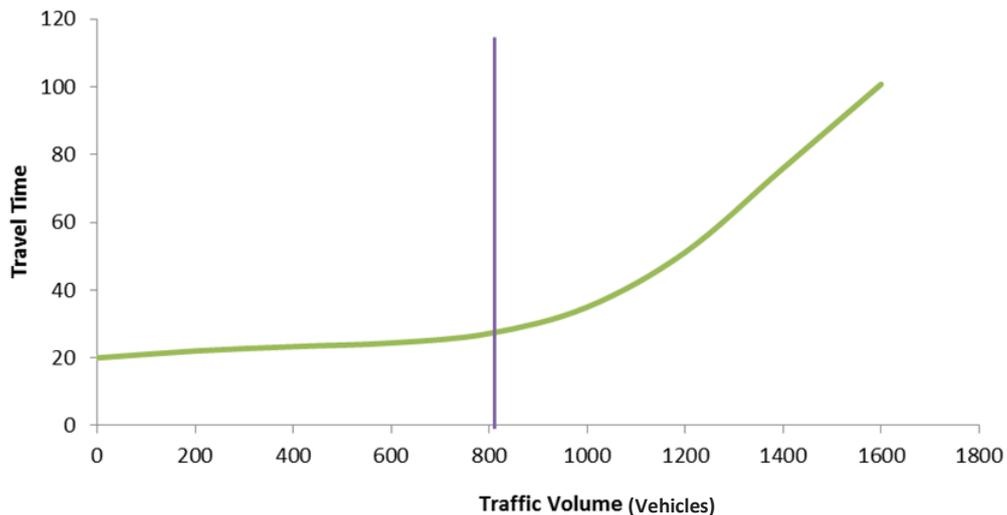
Given the variety of definitions employed across the literature, a number of counterfactual scenarios were tested against the actual traffic conditions on the road network:

- **Free Flow**: Represents a situation where no additional traffic exists on any on the network links. Therefore, this scenario is based on the assumed journey time between links if only one car made the journey.
- **80% Capacity**: This scenario caps all links operating at over 80% capacity to their traffic speeds and journey times at 80% capacity
- **100% Capacity**: This scenario caps all links operating at over 100% capacity to their journey time and traffic speed properties at 100% capacity.

Thus, to measure the level of congestion being experienced on the network we analyse the difference between the counterfactual scenario and the conditions observed in current conditions:

- **Congested**: This scenario represents what is assumed to be the normal work day traffic flows during the AM, IP and PM peaks (as of 2012).

B.5   Calculating Costs of Congestion

Having defined congestion and set out a methodology for calculating it, this needs to be operationalised in the analysis. To analyse the cost of congestion, we model the outputs under the current scenario and what would occur when the network is operating under each of the counterfactual scenarios. The difference between these two analyses is then termed the impact of congestion.

The analysis is undertaken across three time periods; in the morning (AM); the afternoon Inter-Peak or IP); and in the evening (PM) reflecting the variety of transport patterns experienced over a day and standard transport appraisal practice. The AM time period covers 0700-0959, the IP covers the period 1000-1559 and the PM covers 1600-1859. For each of these time periods a one-hour period is modelled by the NTA ERM; 0800-0900 for AM, 1200-1300 for IP and 1600-1700 from PM. Using annualisation factors[3], the results from these three hours can be factored up to give an estimate for annual values. The results of the IP hour are used to estimate the off-peak (OP) time period; 1900-0659. The annualisation factors used in this report are displayed in Table 8 below. These are the factors developed by the NTA to use with the iteration of the model used in this research and were derived from the National Household Travel Survey (NHTM) undertaken in 2012 and calculated based on the profile of trips in travel diary records.

Table B.1: Annualisation Factors

	Highway	Public Transport
AM	641	536
IP	4403	3556
PM	704	630

As outlined in the literature review, a number of costs are associated with congestion and the following details what is included in this analysis and how it was applied.

<u>Value of Time</u>

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[3] Annualisation factors are a standard feature of transport appraisal and analysis methodology. The factors themselves take account of time of the day and day of the week which then allow for an estimation of annual impacts.

The first and primary cost of congestion is the time lost to delay arising for each affected journey. To estimate the delay between the current level of operation and the congestion scenarios, the ERM transport model was utilised. The model was built using the highway modelling programme SATURN. SATURN uses two equations to calculate the link travel time at each link in the modelled network. Equation A is used to calculate the link travel time for link at or below capacity while equation B is used to calculate link travel time over capacity.

(A) $t_i = AV^n + t_0$
(B) $t_i = AC^n + t_0 + B(V - C)/C$

t_i – Link travel time
t_0 – Free-flow travel time (in seconds),
A – Coefficient calculated by SATURN
C – Link capacity
V – Link volume
n – Coefficient calculated by SATURN
B – Constant worked out by SATURN equal to one half the time period being modelled

Using these two equations SATURN produces the travel times for all links in the ERM network. These values are taken as the congested time. To get travel times for the lower 80% and higher 100% scenarios, the same equations are manually applied using the ERM run values, flow and capacity, to calculate a capped link time for all links in the ERM without affecting route choice. By analysing the difference between scenarios we can observe the estimated level of delay in seconds in the ERM test area. To arrive at an economic cost for this loss of time we apply the concept of value of time. Value of time is a parameter frequently used in the appraisal and analysis of transport projects. The precise value is an estimation of what a period of time is worth to each person and it varies by journey purpose such as in-work travel time, leisure time and commuting. The values utilized in this study are listed in Table B.2.

In completing this analysis the journeys were split between the journey purposes and modes highlighted in Table B.2 and the relevant value of time as applied to the difference between current condition and those arising in the various other scenarios.

From the outset of this study we intended to model the cost of emissions and vehicle operating costs as a result of congestion in the Greater Dublin Area. However, as will be further detailed below, current modelling developments and capacity precluded this analysis from being included. As previously stated, DTTaS envisages this report as being the

first element of a national project. As such it is intended to return to these areas at a later stage. It is also worth noting that other international studies on congestion and typical transport appraisals find that the value of time is responsible for 90%+ of the actual calculated impact (excluding wider economic impacts).

Table B.2: Value of Time

Type	User Class	Value of Time €/Hour (2012)	Value of Time €/Hour (2033)
Personal Vehicle	Car Employer	€28.36	€47.61
	Car Commute	€8.68	€14.58
	Car Education	€7.79	€13.08
	Car Other	€7.79	€13.08
Goods Vehicle	LGV	€28.36	€47.61
	OGV1	€28.36	€47.61
	OGV2 Permit Holder	€28.36	€47.61
	OGV2	€28.36	€47.61
Bus	Bus General	€8.68	€14.58
	School	€7.79	€13.08
	Free Travel	€7.79	€13.08
Taxi	Taxi	€7.79	€13.08

B.6   Other costs of congestion

This research report focuses specifically on the direct impact of the delays on road users. When congestion is above acceptable levels, however, there are wider external impacts on the wider population and the Irish economy as a whole. These impacts have not been assessed for this report, as the model used was not, at the time, equipped to measure them. However, the cost of congestion study carried out by New Zealand Transport Authority estimated that the value of time impact accounted for 92.5% of the total cost, which included emissions and environmental costs, vehicle operating costs and indirect costs such as schedule delay costs. In addition a similar report compiled by Travel Canada found that the value of time lost to congestion was responsible for more than 90% of the total cost.

Neither of these studies estimated 'wider economic impacts' – these have the potential to be substantial. This section briefly describes these impacts.

Wider economic impacts

Congestion above acceptable levels also has an impact on the wider economy, and Ireland's competitiveness. All other things equal, high levels of congestion will reduce the attractiveness of a location to work and live in. This would reduce the ability of the GDA to attract workers, or at least drive up the wages needed to persuade workers to locate here. Congestion will also negatively impact agglomeration (the economic benefits of populations and firms being located closer together). These impacts, and the other increased costs of doing business previously discussed, could reduce the attractiveness of Ireland as a place for foreign firms to locate or to do business in.

Emissions and environmental costs

In increasing the amount of time vehicles are active on the network, congestion increases the amount of emissions from those vehicles. This has negative climate change impacts as it increases the amount of greenhouse gases in the atmosphere. In addition to the negative impact of congestion on emissions, there is also a negative impact on local air, noise and water quality.

Vehicle operating costs

The increased length of time that vehicles spend on the network increases the vehicle operating costs for users, primarily through increased fuel costs.

Wider impacts on road users

In addition to the travel time delay, there are further, indirect, costs of congestion on road users. The first is schedule delay, which is the cost to transport users if the level of congestion causes them to alter their travel plans by leaving their origin either early or late so as to avoid congestion.

There are also costs if congestion leads to low reliability (the ability to predict journey times). If journey times are unpredictable, users may have to leave excessively early to mitigate the risk of being late, or choose a route or mode of transport that would otherwise not be their preference.

Impacts on other transport users

Congested roads also have impacts on users of other modes. Road congestion directly impacts cyclists, who may also experience increased delay. And increased congestion means more people will switch to public transport, potentially leading to reduced journey quality as a result of increased crowding on services.