Gardiner, D. and O'Mahony, M. (2025) Are Broadband, Computer and Transport Access Inequity Interrelated? 104th Annual Meeting of the Transportation Research Board, Washington D.C. Jan. 2025.

Are Broadband, Computer and Transport Access Inequity Interrelated?

Declan Gardiner
Trinity Centre for Transport Research
Department of Civil, Structural & Environmental Engineering
Trinity College Dublin
Dublin
Ireland
Email: gardined@tcd.ie

Margaret O'Mahony
Trinity Centre for Transport Research
Department of Civil, Structural & Environmental Engineering
Trinity College Dublin
Dublin
Ireland
Email: margaret.omahony@tcd.ie

ABSTRACT

Connectivity has become a major issue in socio-economic growth in today's world. A significant pressure exists on individuals to be connected to society, especially in terms of mobility and technology. This paper examines trends in connectivity in Ireland in the context of accessibility to transport, computer availability and access to broadband. The paper identifies whether certain areas suffer from lack of connectivity and where this inequity exists. Though literature and media exist on certain types of connectivity inequity, few studies have examined whether multiple forms of inequity are interrelated.

The study uses Multinomial Logistic (MNL) regression analysis to analyse Irish census data. Inequity was found in transport, broadband and computer access and there appeared to be a degree of interrelatedness between them. How the different levels of access related to deprivation of an area was a key focus of the work. As expected, the proportion of households with broadband and computer access is higher in cities. There are a higher proportion of private transport users in rural areas and a higher mean number of cars per households. Private transport users are more likely to have a long commute time. The proportion of working higher and lower professionals is an indicator of whether broadband and computer access are common in an area. Broadband access is more likely in areas where male unemployment is low, while the affluence of an area affects the likelihood of homes having computer access.

INTRODUCTION

Connectivity is an increasingly important requirement today. Locations that suffer from a lack of connectivity can also suffer from consequent social exclusion (*1*) and this can have a very detrimental impact on the life of an individual. Understanding the need for transport, computer and broadband access and, their interrelatedness is important to help identify how failures in the supply of these crucial infrastructures can impact on living standards.

The need for access to public transport has been well documented (*2*) and governments have put significant measures in place in recent years to encourage its use (*3*). The rise in the use of, and indeed dependency on, computers and latterly broadband has been revolutionary to the point where access to both has become not a luxury but a fundamental necessity in recent years. There is now a key requirement for people to be literate in a technological context (*4*) due to an increase in the use of computers and internet features in every aspect of daily life.

Transport

Lack of accessibility to transport is a barrier to opportunity and one which can exacerbate social exclusion in many rural areas. Publically available online resources for GIS assessment can be utilized to promote distributive justice, as transportation practitioners design, analyze alternatives, and assess community impacts of transportation projects (*5*). Despite a prosperous economy in Ireland, there has been a lack of commitment to rural infrastructural deficiencies particularly in terms of public transport (*6*). Other research found that respondents in a younger age bracket were more likely to be less satisfied with public transport than older respondents (*7*). This was despite the fact that the younger respondents reported a more frequent use of public transport. Another study identified hotspots in Ireland where forced car ownership is most prevalent and is more likely to be in cases where citizens have low public transport accessibility and have a lower income than the national average (*8*).

Studies have also shown that satisfaction with their commute can have a direct impact on subjective well-being and quality of life of individuals (*9*). With passengers becoming increasingly environmentally conscious, and valuing sustainability more, their behaviours become more eco-friendly (*10*). A transportation app was used to collect data about transportation behaviours among underserved population members to ensure equitable transportation planning (11). Overall accessibility and equity level of the highway network were found to be higher than that of the railway, and temporal accessibility in some regions was significantly different, whereas the spatial accessibility in others indicated the most unfair distribution (*12*).

Computer and Broadband Access

Remote connectivity is becoming increasingly important as shown during the COVID-19 pandemic. Computer and internet access have revolutionized the amount of information available to the average person that has the means and interest to explore it (*13*). An experiment conducted (*4*) found that differences in access to home computers translate into disparities in computer skills, which may have negative consequences for future educational, labour market and other economic outcomes.

Previous research has shown that digital inequalities still exist (*4, 13, 14*). Low-income communities have struggled with gaining access to computers and internet technology due to a lack of resources and opportunities. Another study (*15*) found that computer access has a different effect on certain individuals, depending on their resources and social categories, these being gender, age, and education.

Broadband offers unlimited opportunities such as improving education using distance learning, working from home or starting independent businesses, making better-informed health decisions and finding lower-priced goods and services (*16*). Broadband access in an area has also been shown to positively impact income growth and negatively influence unemployment growth (*17*). These impacts have a strong effect on attracting business to an area and increasing income generation (*18*), among the other advantages of broadband access outlined above. Other research (*19*) used a new measure of broadband adoption to study community-level education impacts and found that broadband adoption is related to higher test scores at the county level; the effect is greatest for Black, Latino, and low-income students.

The geography of broadband infrastructure and investments was found to result in variable service provision, and therefore, large disparities exist in access and performance within different geographical locations (*20*). Although average broadband speeds have improved over time, inequity was found to emerge between different societal groups and locations. This inequity especially exists in rural areas as these areas lag urban areas in terms of broadband availability and speed (*21*).

The Irish Central Statistics Office (CSO) data indicated that 91% of households in the country had an internet connection (*22*). Fixed broadband connection was highest in the Dublin region at 92%, compared with the Border and Midland regions, at 71% and 69% respectively. Other data from the CSO (*23*) indicated that internet usage in the previous three months was extremely high in the 16 to 29 years age group, with 96% of these users using the internet daily. Despite availability of broadband, a study (*24*) found that Ireland was slower than many other developed countries to introduce the fastest forms of broadband access.

With these points in mind, the first objective of the research was to study and analyse Irish census data to gain insight into local levels of connectivity to transport, broadband and computers in Ireland. A further objective is to determine whether relationships exist between the level of deprivation in an area and the levels of connectivity in that area across the three key platforms of transport, computer and broadband. A wide range of socio-economic variables will be investigated to assess their importance to accessibility to the three platforms. The final objective was to explore how transport, computer and broadband access may be interrelated.

METHODS

Data

Data for the 2016 National Census Small Area Population Statistics (SAPS) was provided by the Central Statistics Office (CSO) (*25*). This SAPS dataset divides Ireland into over 3,409 regions and the focus of the research presented here was on the answers to census questions on commuting, motor car availability, person computer (PC) ownership and internet access themes.

Another dataset used in the analysis was the 2016 Census Deprivation Index database (*26*) as the data outlines several key factors when investigating inequity. It examines the comparative deprivation of each small area in Ireland based on certain factors.

The factors considered in the analysis what they measure are:

- Total population of an area.
- Age dependency ratio: the percentage of people in an area outside the working age of 15-64.
- Lone parent ratio: the percentage of lone parent households in an area.
- Proportion with third level education: the percentage of population in an area with a third level degree.
- Male and female unemployment rate: the percentage of each gender within the working age in an area without a job.
- Proportion of owner-occupied households: the percentage of households in an area occupied by the legal owner of the household.
- Absolute Deprivation Index (ADI) score: allocated deprivation rating of an area based on a relative scoring system developed by (*26*).
- Proportion of higher and lower professionals: the percentage of people in an area employed as qualified professionals and qualified associate professionals or technicians.

Modelling Method

Multinomial logistic (MNL) regression, where an outcome (dependent) variable that is categorical can be predicted using predictor (independent) variables that are continuous or categorical, was used in the analysis (*27*). It is possible to compare a reference category to several different categories rather than just one by breaking the dependent variable down into a series of comparisons between two categories. Mathematically, MNL regression can be represented in the following form (*27*):

$$P(Y) = \frac{1}{1 + e^{-(b_0 + b_1 X_1 + \ldots + b_n X_n + \varepsilon)}}$$

- P(Y) = Probability of Y occurring, in this case that the area falls into one of the categories examined
- b = Regression coefficient
- X = Predictor/Independent variable
- Ɛ = Random error term

Modelling Scenarios

The relationship between connectivity and deprivation of an area was the first analysis conducted. Several models were set up to examine this as shown in **Table 1**. Each model used a specific set of independent variables selected based on their potential contribution in helping predict the dependent variable (see **Table 1**). The first three models examined the relationship between deprivation and access. The following three were used to examine commuters' habits in terms of the method of commute, the time of their commute and the deprivation index score for the area in which they lived. The dependent variable and its categories are presented in **Table 1** along with the independent variables with explanations as to why they were chosen.

TABLE 1. Connectivity and deprivation model description (note Ref: means reference category)

Model	Independent Variables	Why
1. Broadband Access	Total Population	Well documented that lower population areas have less access to broadband.
<40% households - very low access	Male Unemployment	Lower household income may result in a lower chance of having broadband.
40-54% households - low access	Lone Parent Ratio	A lone parent household often has a lower income.
55-69% households - medium access	Proportion with third level education	Households with college students may require broadband.
70-85% households - high access	Proportion of higher and lower professiona	Households with working professionals may require broadband.
>85% households - very high access (Ref)	Absolute Deprivation Index Score	Examine whether lack of broadband is a factor in deprivation.
2. Computer Access	Male Unemployment	Lower household income may result in a lower chance of owning a computer.
<55% households - very low access (Ref)	Lone Parent Ratio	A lone parent household often has a lower income.
55-64% households - low access	Proportion with third level education	Households with college students may require computer access.
65-75% households - high access	Proportion of higher and lower professiona	Households with working professionals may require computer access.
>75% households - very high access	Absolute Deprivation Index Score	Examine whether lack of computer access is a factor in deprivation.
3. Number of Cars	Total Population	More populated places tend to have more access to public transport.
<1.2 cars / household - very low #cars (Ref)	Male Unemployment	Lower household income may result in less cars bought.
1.2-1.382 cars / household - low #cars	Female Unemployment	Lower household income may result in less cars bought.
1.383-1.565 cars / household - medim #cars	Lone Parent Ratio	A lone parent household may require a fewer number of cars.
1.565-1.749 cars / household - high #cars	Proportion of owner occupied households	Rented households may be less likely to own a number of cars than owned households.
>1.75 cars / household - very high #cars	Absolute Deprivation Index Score	Examine whether the number of cars/household is a factor in deprivation.
4. Commute Type – Private Transport	Total Population	More populated places tend to have more access to public transport.
<53% commuters using private transport - very low PrivateT (Ref)	Age Dependency Ratio	Areas with a lower age dependency ratio more likely to commute to school and work.
53-61% commuters using private transport - low PrivateT	Proportion of owner occupied households	Rented households may be less likely to use cars for commute than owned households.
62-70% commuters using private transport - medium PrivateT	Proportion of higher and lower professiona	Areas with a high number of professionals more likely to have higher commuting times.
71-79% commuters using private transport - high PrivateT	Absolute Deprivation Index Score	Examine whether the mode of commute is a factor in deprivation.
>80% commuters using private transport - very high PrivateT		
5. Commute Type - Public Transport	Total Population	More populated places tend to have more access to public transport.
<5% commuters using public transport - very low PublicT (Ref)	Age Dependency Ratio	Areas with a lower age dependency ratio more likely to commute to school and work.
5-9% commuters using public transport - low PublicT	Proportion of owner occupied households	Rented households may be less likely to use cars for commute than owned households.
10-14% commuters using public transport - medium PublicT	Proportion of higher and lower professiona	Areas with a high number of professionals more likely to have higher commuting.
15-19% commuters using public transport - high PublicT	Absolute Deprivation Index Score	Examine whether the mode of commute is a factor in deprivation.
>20% commuters using public transport - very high Public T		
6. Commute Type - On foot/Bicycle	Total Population	More populated places tend to have a shorter commute.
<3% commuters walking/cycling - very low Walk_Cycle (Ref)	Age Dependency Ratio	Areas with a lower age dependency ratio more likely to commute to school and work.
3-5% commuters walking/cycling - low Walk_Cycle	Proportion of owner occupied households	Rented households may be less likely to use cars for commute than owned households.
6-8% commuters walking/cycling - medium Walk-Cycle	Proportion of higher and lower professiona	Areas with a high number of professionals more likely to have higher commuting.
9-11% commuters walking/cycling - high Walk-Cycle	Absolute Deprivation Index Score	Examine whether the mode of commute is a factor in deprivation.
12% commuters walking/cycling - very high Walk_Cycle		

Once the models in **Table 1** had been completed, connectivity was further examined, again using MNL regression, to identify which areas in Ireland suffer from lack of connectivity and whether some of these areas suffer from multiple forms of connectivity deprivation. The locations were examined at two levels, (i) city and rural areas, and (ii) Regional Authority (RA) areas. Analysis was also conducted to determine whether an area's deprivation score was related in the same way to different forms of connectivity. How these relationships were modelled and analysed is outlined below.

Broadband and Computer Access vs Number of Cars in a Household

Two separate models were used to obtain a relationship between broadband access and the number of cars in a household and computer access and the number of cars in a household. The car ownership variable was the proportion of houses in an area with no cars, 1 car and 2 cars, respectively. These variables, labelled NoCarPop, OneCarPop and TwoCarPop, were then used as the independent variables. A similar method was used to set up the computer access / car ownership model.

Commute Type vs Commute Time

To examine more fully transport inequity, three further models were run focusing on commuter habits and to examine the mode of commuting and the time taken for that trip. The forms of transport examined were private transport, public transport and active modes. The dependent variables and categories for all models remained the same as outlined earlier. The independent variables were defined by finding the proportion of commuters with a commute time of under 30 minutes (U30minProp), 30 to 59 minutes (U60minProp) and an hour or more (60+minProp) respectively in an area.

Connectivity vs Location

Location and its relationship with connectivity was examined at two levels (i) city and rural areas and (ii) RA areas. All areas within cities were defined as urban and all other areas were defined as rural. These designations were dictated by the census data, and it was not possible to work at a more granular level. It should be noted, on this basis, that large towns in rural areas would have been classed as rural in the analysis.

There were eight RAs in Ireland in 2016, which covered several counties in most cases. Using the two different geographical levels mentioned above the influence of where an area is situated on its connectivity could be measured. The factors of connectivity that were analysed for MNL regression were very similar to the first round of MNL regression analysis, but commute time was also examined.

Deprivation Score as a Dependent Variable

Modelling the Deprivation Score as a dependent variable was the final model examined (*26*). Areas were given a deprivation rating based on their score relative to all other area's scores. The areas were then categorised by their rating to obtain a dependent variable. The categories for this variable were: less than -10 = Very Deprived (Ref), Deprivation score of -10 – -6.1 = Deprived, Deprivation score of -6.1 – -2.1 = Medium, Deprivation score of -2.1 – 1.9 = Prosperous, Deprivation score of 2 or more = Very Prosperous. The proportion of houses in an area with no cars, 1 car and 2 cars were again used as independent variables. The proportion of computer and broadband access that had previously been used to categorise areas based on their connectivity were also used as continuous independent variables.

RESULTS

The MNL results table for the model examining broadband access and deprivation is provided in **Table 2**. The Nagelkerke R^2 value of 0.388 indicates a model of acceptable level of significance. The reference category is very high broadband access and shading in the table indicates statistical significance at the $p < 0.05$ level.

TABLE 2. MNL parameter estimates for the Model 1: broadband access vs deprivation

Broadband Access vs Deprivation							
Area Access[a]					95% Confidence Interval for Exp(B)		
		B	Std. Error	Sig.	Exp(B)	Lower Bound	Upper Bound
Very Low Access	Intercept	12.745	1.594	0.000			
	LoneParent	-0.115	0.029	0.000	0.891	0.843	0.943
	HighEducation	-0.050	0.038	0.190	0.951	0.883	1.025
	MaleUnemploy	0.216	0.087	0.013	1.241	1.047	1.471
	TotalPopulation	-0.002	0.000	0.000	0.998	0.998	0.999
	DeprivationScore	0.027	0.112	0.809	1.027	0.825	1.279
	HighLowPro	-0.175	0.028	0.000	0.840	0.795	0.887
Low Access	Intercept	14.677	1.482	0.000			
	LoneParent	-0.104	0.028	0.000	0.901	0.854	0.952
	HighEducation	-0.077	0.035	0.029	0.926	0.864	0.992
	MaleUnemploy	0.244	0.085	0.004	1.276	1.080	1.509
	TotalPopulation	-0.001	0.000	0.000	0.999	0.999	0.999
	DeprivationScore	0.132	0.108	0.221	1.141	0.924	1.408
	HighLowPro	-0.206	0.030	0.000	0.814	0.768	0.862
Medium Access	Intercept	14.215	1.437	0.000			
	LoneParent	-0.090	0.027	0.001	0.914	0.866	0.965
	HighEducation	-0.049	0.034	0.153	0.952	0.891	1.018
	MaleUnemploy	0.233	0.085	0.006	1.263	1.069	1.491
	TotalPopulation	-0.001	0.000	0.000	0.999	0.999	0.999
	DeprivationScore	0.135	0.106	0.205	1.144	0.929	1.408
	HighLowPro	-0.212	0.029	0.000	0.809	0.765	0.856
High Access	Intercept	9.757	1.383	0.000			
	LoneParent	-0.061	0.027	0.026	0.941	0.892	0.993
	HighEducation	0.008	0.033	0.812	1.008	0.945	1.075
	MaleUnemploy	0.176	0.085	0.037	1.192	1.010	1.407
	TotalPopulation	0.000	0.000	0.000	1.000	1.000	1.000
	DeprivationScore	0.096	0.105	0.359	1.101	0.896	1.351
	HighLowPro	-0.175	0.028	0.000	0.840	0.795	0.887
a. The reference category is: Very High Access R^2 = .388 (Nagelkerke)							

Note: The variable names explained as: LoneParent – lone parents' ratio, HighEducation – proportion with third level education, MaleUnemploy – male unemployment rate, FemaleUnemploy – female unemployment rate, TotalPopulation – An area's total population, DeprivationScore – Absolute Deprivation Index score, HighLowPro – Proportion of higher and lower professionals, AgeDependency – Age dependency ratio, OwnersHouse – Proportion of owner-occupied households

When the B coefficients or odds ratios (Exp(B)) are examined, the following conclusions can be drawn.

- An area with a high proportion of male unemployment is less likely to be an area with very high broadband access.
- An area with a high proportion of higher and lower professionals is more likely to be an area with very high broadband access.
- An area with a high lone parent ratio is more likely to be an area with high broadband access than low and very low access.

Results for Model 2, the computer access vs deprivation model resulted in a model with a Nagelkerke R^2 value of 0.422 and this exceeded the required threshold for model significance of 0.25 (*27*). The table of result outputs are not included due to space limitations. It was found that the lone parent, higher education and male unemployment variables were not significant. The reference category in this case was the low access category. Deprivation score and the number of professionals in an area were found to be statistically significant variables for this model. If an area's deprivation score is increased by a unit of 1 (deprivation is decreased), the change in odds (CIO) of the area being in the high rather than low access category is 1.163 and in the very high rather than low access category is 1.205; indicating that an area that is affluent is less likely to be an area with low computer access. If the proportion of higher and lower professionals in area is increased by 1, the CIO of the area being in the high rather than low access category is 1.112 and in the very high access category rather than the low access category is 1.218; indicating that an area that has a high proportion of higher and lower professionals is less likely to be an area with low computer access than high and very high access.

The results for Model 3, number of cars per household (CPH) vs deprivation, are shown in **Table 3.** This model was also found to be substantively significant, with a Nagelkerke R^2 value of 0.495.

Examining the B and/or the Exp(B) values in the table, the following conclusions can be drawn.

- An area with a high lone parent ratio is more likely to be an area with a very low mean number of CPH.
- An area with a high proportion of male unemployment is more likely to be an area with a very low mean number of CPH than an area with a high and very high mean number of CPH.
- An area that is affluent is less likely to be an area with a very low mean number of CPH than an area with a very high mean number of CPH.
- An area with a high proportion of owner-occupied households is less likely to be an area with a very low mean number of CPH than an area with a high and very high mean number of CPH.

Table 4 shows the results found for the relationships between private transport and deprivation (Model 4). The Nagelkerke R^2 value, of 0.306, showed sufficient significance in the model and the results have been interpreted below.

TABLE 3. MNL parameter estimates for the car ownership vs deprivation model.

No. of Cars vs Deprivation							
#Cars[a]					95% Confidence Interval for Exp(B)		
		B	Std. Error	Sig.	Exp(B)	Lower Bound	Upper Bound
Low #Cars	Intercept	-1.987	0.942	0.035			
	LoneParent	-0.101	0.013	0.000	0.904	0.882	0.927
	MaleUnemploy	-0.072	0.025	0.003	0.930	0.886	0.976
	FemaleUnemploy	0.058	0.026	0.025	1.060	1.007	1.114
	TotalPopulation	0.000	0.000	0.147	1.000	1.000	1.000
	DeprivationScore	-0.070	0.030	0.019	0.933	0.880	0.988
	OwnersInHouse	0.058	0.009	0.000	1.059	1.041	1.078
Medium #Cars	Intercept	-3.637	0.960	0.000			
	LoneParent	-0.116	0.012	0.000	0.891	0.869	0.913
	MaleUnemploy	-0.104	0.024	0.000	0.901	0.860	0.945
	FemaleUnemploy	0.066	0.025	0.009	1.068	1.016	1.122
	TotalPopulation	0.000	0.000	0.151	1.000	1.000	1.000
	DeprivationScore	-0.064	0.028	0.024	0.938	0.887	0.992
	OwnersInHouse	0.095	0.009	0.000	1.099	1.080	1.120
High #Cars	Intercept	-6.118	1.025	0.000			
	LoneParent	-0.117	0.013	0.000	0.889	0.868	0.912
	MaleUnemploy	-0.120	0.025	0.000	0.887	0.845	0.931
	FemaleUnemploy	0.090	0.025	0.000	1.094	1.041	1.150
	TotalPopulation	0.000	0.000	0.004	1.000	1.000	1.000
	DeprivationScore	0.002	0.029	0.938	1.002	0.947	1.060
	OwnersInHouse	0.134	0.010	0.000	1.143	1.121	1.166
Very High #Cars	Intercept	-10.635	1.255	0.000			
	LoneParent	-0.125	0.014	0.000	0.882	0.858	0.908
	MaleUnemploy	-0.091	0.028	0.001	0.913	0.865	0.964
	FemaleUnemploy	0.092	0.028	0.001	1.097	1.038	1.158
	TotalPopulation	0.000	0.000	0.004	1.000	1.000	1.000
	DeprivationScore	0.122	0.031	0.000	1.130	1.062	1.201
	OwnersInHouse	0.181	0.012	0.000	1.198	1.169	1.227

a. The reference category is: Very Low #Cars

R^2 = .495 (Nagelkerke)

TABLE 4. MNL parameter estimates for the private transport vs deprivation model. (Model 4)

Private Transport vs Deprivation							
PrivateT Rating[a]					95% Confidence Interval for Exp(B)		
		B	Std. Error	Sig.	Exp(B)	Lower Bound	Upper Bound
Low PrivateT	Intercept	-5.279	0.786	0.000			
	AgeDependency	0.142	0.025	0.000	1.153	1.098	1.211
	OwnersInHouse	0.059	0.007	0.000	1.061	1.047	1.075
	HighLowPro	-0.092	0.019	0.000	0.912	0.879	0.946
	DeprivationScore	0.111	0.029	0.000	1.118	1.055	1.184
Medium PrivateT	Intercept	-7.018	0.765	0.000			
	AgeDependency	0.169	0.023	0.000	1.184	1.132	1.239
	OwnersInHouse	0.096	0.006	0.000	1.101	1.087	1.114
	HighLowPro	-0.124	0.017	0.000	0.884	0.854	0.914
	DeprivationScore	0.140	0.027	0.000	1.151	1.092	1.213
High PrivateT	Intercept	-6.925	0.759	0.000			
	AgeDependency	0.161	0.023	0.000	1.175	1.124	1.229
	OwnersInHouse	0.114	0.007	0.000	1.121	1.107	1.135
	HighLowPro	-0.145	0.017	0.000	0.865	0.837	0.894
	DeprivationScore	0.200	0.027	0.000	1.221	1.159	1.288
Very High PrivateT	Intercept	-9.720	1.081	0.000			
	AgeDependency	0.152	0.027	0.000	1.164	1.104	1.227
	OwnersInHouse	0.137	0.009	0.000	1.147	1.127	1.168
	HighLowPro	-0.145	0.020	0.000	0.865	0.833	0.899
	DeprivationScore	0.247	0.032	0.000	1.280	1.202	1.363

a. The reference category is: Very Low PrivateT.

R^2 = .306 (Nagelkerke)

The main findings include:

- An area with a high age dependency is less likely to be an area with very low private transport use.
- An area with a high proportion of owner-occupied households is less likely to be an area with very low private transport use than high and very high transport use.
- An area with a high proportion of higher and lower professionals is more likely to be an area with very low private transport use than high, very high and medium transport use.
- An area that is affluent is less likely to be an area with very low private transport use compared with other categories.

Model 5 examined the relationship between public transport and deprivation, but this model resulted in very few significant variables. While the Nagelkerke R^2 value of 0.287 showed an acceptable level of significance, the only variable showing significance was the deprivation score. The main finding was that an affluent area is more likely to be an area with very low public transport use.

Model 6 explored the relationship between a walking or cycling commute and deprivation and had a Nagelkerke R^2 value of 0.347 but only one statistically significant variable. The main conclusion was that a high proportion of owner-occupied households is more likely to be an area with very low walk/cycle commuting than high and very high walk/cycle commuting categories.

Further Investigation

As mentioned earlier another set of models were run to further investigate other factors. Location was tested as an independent variable in each of the models constructed. In most of these cases, there were two levels of location tested separately (i) city and rural areas and (ii) Regional Authority areas. This resulted in two sets of results for each model. In all models tested, it was found that the results were consistent in both models for the other independent variables tested (number of cars per household and commute time), but regression coefficients and adjusted odds ratio values differed slightly. Due to paper length restrictions, the parameter estimates tables are not presented but the main conclusions from each model are discussed below. Both sets of results are considered, however, interpretation has only been shown for one set of results in each case. This does not apply to the models where location was the only independent variable or where location was not tested, which have only one set of results.

Broadband and computer access vs car ownership model results

The first model examined was used to test the relationship between the proportion of houses with broadband access in an area and the proportion of households with zero, one and two cars respectively. The model also examined the relationship between broadband access and the location of an area. The model where the location variable examined rural and city areas had a Nagelkerke R^2 value of 0.3, while the model where the location variable examined RA areas had a Nagelkerke R-square value of 0.316. Both values suggested that each model was substantively significant. Due to the higher significance of the RA model, its results will be the focus on the discussion below. The following conclusions can be drawn from the model.

- An area with a high proportion of households with no car is more likely to be an area with very low broadband access than very high broadband access but is less likely to be an area with very low broadband access than medium and low broadband access.
- An area with a high proportion of households with one car is less likely to be an area with very low broadband access than very high broadband access but is more likely to be an area with very low broadband access than medium and low broadband access.
- No useful conclusions could be drawn from the results regarding which RA an area was in. However, in the city/rural model, the results suggest that an area that is in a city is significantly more likely to not be in the very low broadband access category than a rural area.

Computer Access vs Number of Cars per Household (CPH) and Location

The results from the model examining the relationship between computer access and CPH as well as the relationship between computer access and location resulted in the following conclusions.

- An area with a high proportion of households with one car is more likely to be an area with very low computer access than high and very high computer access.
- An area with a high proportion of households with two cars is less likely to be an area with very low computer access.
- An area that is in a city is more likely to be in the high and very high computer access categories compared to the very low access category than a rural area.
- An area that is in the Border RA is more likely to be an area with very low computer access than very high computer access.
- An area that is in a rural area is more likely to have a higher mean number of CPH than a city area.
- An area that is in the Border RA is more likely to have a very low mean number of cars per household than a high mean number of CPH.

Commute Type vs Commute Time and Location

Three modes of commute were examined for their relationship with commute time and location. Each mode generated two sets of results as the location variables were tested separately in all cases. The first mode of commute examined was private transport. The results suggest the following:

- An area with a high proportion of commuters with a commute time under 30 minutes is less likely to be an area with very low private transport use than high, very high and medium use.
- An area with a high proportion of commuters with a commute time of an hour or more is less likely to be an area with very low private transport use.
- An area that is in a rural area is more likely to be an area where private transport use is high than a city area.
- An area that is in the Border RA is less likely to be an area where there is a very low use of private transport for commuting.

The results from the models focused on public transport suggest the following:

- An area with a high proportion of commuters with a commute time under 30 minutes is more likely to be an area with very low public transport use.
- An area with a high proportion of commuters with a commute time of 30 to 59 minutes is less likely to be an area with very low public transport use.
- An area with a high proportion of commuters with a commute time of an hour or more is less likely to be an area with very low public transport use than high, very high and medium use.
- An area that is in the Border RA is less likely to be an area where there is a very low use of public transport for commuting than high, very high and medium use.
- An area that is in the Dublin RA, Mid-East RA or Midlands RA is less likely to be an area where there is a very low use of public transport for commuting.
- An area that is in the Mid-West RA is more likely to be an area where there is a very low use of public transport for commuting.
- An area that is in a rural area is less likely to be an area where there is a high or very high use of public transport for commuting than a city area.

The final commuting model focused on the walk or cycle mode of commute, the conclusions from which are as follows:

- An area with a high proportion of commuters with a commute time under 30 minutes is less likely to be an area with a very low proportion of people walking or cycling on their commute.
- An area with a high proportion of commuters with a commute time of 30 to 59 minutes is more likely to be an area with a very low proportion of people walking or cycling on their commute.
- A rural area is more likely to be an area with a very low proportion of people walking or cycling on their commute than a city area.

Model to examine interrelatedness of broadband access, computer access, transport access and deprivation.

The final set of model results examined deprivation as the dependent variable and investigated the interrelatedness of broadband and computer access and number of cars per household. The results for this model are shown in **Table 5**. A Nagelkerke R^2 value of 0.434 indicated sufficient substantive significance of the model.

TABLE 5. MNL parameter estimates for deprivation and connectivity.

Deprivation vs Connectivity							
Deprivation Rating[a]					95% Confidence Interval for Exp(B)		
		B	Std. Error	Sig.	Exp(B)	Lower Bound	Upper Bound
Deprived	Intercept	-5.280	0.643	0.000			
	BbandAccess	-0.027	0.007	0.000	0.973	0.960	0.986
	CompAccess	0.118	0.013	0.000	1.125	1.096	1.155
	NoCarPop	0.300	0.801	0.708	1.350	0.281	6.484
	OneCarPop	-2.055	0.615	0.001	0.128	0.038	0.428
	TwoCarPop	1.348	0.423	0.001	3.850	1.682	8.815
Medium	Intercept	-8.363	0.792	0.000			
	BbandAccess	-0.028	0.007	0.000	0.973	0.959	0.986
	CompAccess	0.170	0.014	0.000	1.185	1.152	1.218
	NoCarPop	1.687	0.975	0.084	5.401	0.799	36.497
	OneCarPop	-5.227	0.750	0.000	0.005	0.001	0.023
	TwoCarPop	3.196	0.564	0.000	24.430	8.093	73.744
Prosperous	Intercept	-14.032	0.798	0.000			
	BbandAccess	-0.041	0.008	0.000	0.960	0.945	0.975
	CompAccess	0.255	0.016	0.000	1.290	1.250	1.331
	NoCarPop	7.014	0.844	0.000	1112.348	212.875	5812.407
	OneCarPop	-6.674	0.665	0.000	0.001	0.000	0.005
	TwoCarPop	3.895	0.446	0.000	49.167	20.496	117.949
Very Prosperous	Intercept	-23.318	1.541	0.000			
	BbandAccess	-0.018	0.01	0.065	0.982	0.964	1.001
	CompAccess	0.374	0.02	0.000	1.453	1.398	1.510
	NoCarPop	10.004	1.602	0.000	22118.915	956.835	511317.255
	OneCarPop	-7.821	1.382	0.000	0.0004	2.671E-05	0.006
	TwoCarPop	1.937	1.289	0.133	6.937	0.555	86.739

a. The reference category is: Very Deprived

R^2 = .434 (Nagelkerke)

The results in **Table 5** suggest the following:

- An area with a high proportion of home computer access is less likely to be a very deprived area.
- The coefficients for broadband access were very small and so not much weight can be given to any conclusions drawn but they suggest that an area with a high broadband access is marginally more likely to be a very deprived area.
- An area with a high proportion of households with no car is less likely to be a very deprived area than a prosperous and very prosperous area.
- An area with a high proportion of households with one car is more likely to be a very deprived area.
- An area with a high proportion of houses with two cars is less likely to be a very deprived area than a prosperous, medium and deprived area.

Results Summary

A summary of the variables of influence of all models considered are presented in **Table 6**. Location is influential in all models and deprivation score is influential in many excluding the broadband access models and the walking/cycling model. Commute time and proportion of owner-occupied households influence widely in the transport access models. The proportion of higher/lower professionals in the population influence both the broadband and computer access models but only one of the transport access models – private transport use.

TABLE 6. Summary of variables of influence in the models.

Broadband access	Computer Access	Transport Access			
		Car ownership	Private transport use	Walking/Cycling	Public transport
Male unemployment	Deprivation Score	Male unemployment	Age dependency ratio	Prop. of owner occupied households	Deprivation score
Prop. of higher/lower prof.	Prop. of higher/lower prof.	Prop. of owner occupied households	Prop. of owner occupied households	Commute time	Commute time
Lone parent ratio	Location	Lone parent ratio	Prop. of higher/lower prof.	Location	Location
Location		Deprivation score	Deprivation score		
		Location	Commute time		
			Location		

DISCUSSION

Inequity is seen to exist in Ireland in the forms of connectivity examined. Rural areas were found to be the most negatively affected by the inequity, with less broadband, computer and transport access existing in these areas. Demographics such as employment and household status and affluence of an area are influencing parts in many forms of connectivity. The results were found to concur with other research (*28*) that shows that geographical disparities and socio-economic factors play a role in the digital divide. They are also aligned with findings (*29*) which show that high levels of broadband adoption in rural areas positively impact income growth and negatively influence unemployment growth. Meanwhile, access to information and communications technology at home is influenced by the family's socio-economic-status (*30*).

The results noted that those in rural areas are more reliant on cars. They also show that people who use private transport have a longer commute. Time spent commuting is a significant factor for the mental wellbeing (*9*). The results also show that deprivation is an influencing factor for car access and the mode of transport used by commuters. It was concluded elsewhere that the priorities of the Irish government are fixed on transport issues within the Greater Dublin Region, with rural transportation issues largely passed to local communities (*6*). Both rural and suburban residents rely on private cars to commute to work because this transport option is more available and more convenient (*31*). Inequality was found to influence overall household transport expenditure, and more specifically on purchase of vehicles and operation of private transport equipment (*32*). It should be noted however, that private transport use is still by far the highest used mode of commute in most regions of Ireland (*25*). This is likely due to the perceived higher reliability of private transport (*33*).

Strengths and Weaknesses

An advantage of using census data was the accessibility and comprehensiveness of the datasets. A thorough testing programme employed was also a strength of the project. Many independent variables tested did not return significant results or may have reduced the substantive significance of a model. Through a process of elimination, models that provided significant results were found.

Weaknesses of the work include the possibility that insufficient granularity of the data may have resulted in some areas being incorrectly designated as urban and rural but the impact of this is likely to be limited. Another potential weakness is that broadband speed was not accounted for as this

information was not available. Most broadband connections in Ireland range from 24Mbps to 100Mbps (*34*). Another potential weakness is the age of the datasets but the most recent data available (the last census) was not available at the time of the research because of delays due to COVID.

CONCLUSIONS

The results of the research provide valuable insights into connectivity inequity, using Irish data for the analyses.

The following key findings were conclusions of the work:

- Inequity exists in Ireland in transport, broadband and computer access and there appears to be a degree of interrelatedness between the access inequity.
- As expected, the proportion of households with broadband and computer access is higher in city areas.
- There are a higher proportion of private transport users in rural areas and a higher mean number of cars per household due to a lack of available infrastructure.
- The proportion of working higher and lower professionals is an indicator in whether broadband and computer access are common in an area.
- Broadband access is more likely in areas where male unemployment is low, while the affluence of an area affects the likelihood of homes having computer access.
- Private transport users are more likely to have a long commute time.

AUTHOR CONTRIBUTIONS

The authors confirm contribution to the paper as follows: study conception and design: D. Gardiner, M. O'Mahony; data collection: D. Gardiner; analysis and interpretation of results: D. Gardiner, M. O'Mahony; draft manuscript preparation: D. Gardiner, M. O'Mahony. All authors reviewed the results and approved the final version of the manuscript.

REFERENCES

1. Church, A., Frost, M. and Sullivan, K. Transport and social exclusion in London, *Transport Policy*, 2000, 7(3), 195–205.

2. Directorate-General for Climate Action *Going Climate-Neutral by 2050*. European Commission. 2019. https://op.europa.eu/en/publication-detail/-/publication/92f6d5bc-76bc-11e9-9f05-01aa75ed71a1. Accessed July 29, 2024.

3. NTA. *Annual Report and Financial Statements 2019*. National Transport Authority. 2019. https://www.nationaltransport.ie/wp-content/uploads/2020/09/NTA-Annual-Report-2019-English.pdf Accessed July 29, 2024.

4. Fairlie, R. W. The effects of home access to technology on computer skills: Evidence from a field experiment, *Information Economics and Policy*, 2012, 24(3–4), 243–253.

5. Spriggs, A., Rotman, R. Trauth, K. Functional analysis of web-based GIS tools for environmental justice assessment of transportation projects. *Transportation Research Part D*, 2024, 128, 104080.

6. McDonagh, J. Transport policy instruments and transport-related social exclusion in rural Republic of Ireland, *Journal of Transport Geography*, 2006. 14(5), 355–366.

7. Ingvardson, J. B. and Nielsen, O. A. The relationship between norms, satisfaction and public transport use: A comparison across six European cities using structural equation modelling, *Transportation Research Part A: Policy and Practice*, 2019. 126, 37–57.

8. Carroll, P., Benevenuto, R. and Caulfield, B. Identifying Hotspots of Transport Disadvantage and Car Dependency in Rural Ireland, *Transport Policy*. 2021. 101, 46-56.

9. De Vos, J. and Witlox, F. Travel satisfaction revisited. On the pivotal role of travel satisfaction in conceptualising a travel behaviour process, *Transportation Research Part A: Policy and Practice*, 2017, 106, 363–373.

10. Vicente, P., Sampaio, A. and Reis, E. Factors influencing passenger loyalty towards public transport services: Does public transport providers commitment to environmental sustainability matter?, *Case Studies on Transport Policy*, 2020, 8(2), 627–638.

11. Cronley, C., O'Dell, A., Fields, N., Mattingly, S.P. Iroz-Elardo, N, Highfill, M.C., Cole, R., Stringfellow. M. K. Designing and evaluating a smartphone app to increase underserved communities' data representation in transportation policy and planning. *Transportation Research Interdisciplinary Perspectives*, 18, 2023, 100763.

12. Tang, H, Li, Y., Li, M., and Shao, Z Accessibility and Equity Analysis of Highway-Railway Traffic Network Based on Real-Time Route Planning Data: A Case Study of Shandong Peninsula Urban Agglomeration, China, Transportation Research Record, 2024, https://doi.org/10.1177/03611981241239963.

13. Araque, J. C., Maiden, R.P., Bravo, N., Estrada, I., Evans, R., Hunchik, K., Kirby, K, Reddy, M. Computer usage and access in low-income urban communities, *Computers in Human Behaviour*, 2013, 29(4), 1393–1401.

14. Beaunoyer, E., Dupéré, S. and Guitton, M. J. COVID-19 and digital inequalities: Reciprocal impacts and mitigation strategies, *Computers in Human Behaviour*, 2020. 111, 106424.

15. Lopez-Sintas, J., Lamberti, G. and Sukphan, J. The social structuring of the digital gap in a developing country. The impact of computer and internet access opportunities on internet use in Thailand, *Technology in Society*, 2020, 63, 101433.

16. Stansberry, K., Anderson, J. and Rainie, L. The internet will continue to make life better, Pew Research Centre. 2019. https://www.pewresearch.org/internet/2019/10/28/4-the-internet-will-continue-to-make-life-better/ Accessed 29 July, 2024.

17. Katz, R. Impact of Broadband on the Economy. Research. International Telecommunications Union, 2012. https://www.itu.int/ITU-D/treg/broadband/ITU-BB-Reports_Impact-of-Broadband-on-the-Economy.pdf Accessed 29 July, 2024.

18. Whitacre, B. and Gallardo, R. State broadband policy: Impacts on availability, *Telecommunications Policy*, 2020, 44(9), p. 102025.

19. Caldarulo, M., Mossberger, K., Howell, A. Community-wide broadband adoption and student academic achievement. *Telecommunications Policy*, 2023, 47, 1, 102445.

20. Riddlesden, D. and Singleton, A. D. Broadband speed equity: A new digital divide?, *Applied Geography*, 2014, 52, 25–33.

21. Perrin, A. *Digital gap between rural and nonrural America persists*, Pew Research Centre. 2019. https://www.pewresearch.org/fact-tank/2019/05/31/digital-gap-between-rural-and-nonrural-america-persists/ Accessed 29 July, 2024.

22. CSO *Household Internet Connectivity.* Central Statistics Office. 2019. https://www.cso.ie/en/releasesandpublications/ep/p-isshh/informationsocietystatistics-households2019/householdinternetconnectivity/ Accessed 29 July, 2024.

23. CSO *Frequency of Internet Usage*. Central Statistics Office. 2019. https://www.cso.ie/en/releasesandpublications/ep/p-isshh/informationsocietystatistics-households2019/frequencyofinternetusage/ Accessed 29 July, 2024.

24. Haller, S. A. and Lyons, S. Effects of broadband availability on total factor productivity in service sector firms: Evidence from Ireland, *Telecommunications Policy*, 2019, 43(1), 11–22.

25. CSO *Census 2016 Small Area Population Statistics*. 2017. https://www.cso.ie/en/census/census2016reports/census2016smallareapopulationstatistics/ Accessed 29 July, 2024.

26. Haase, T. and Pratschke, J. The 2016 Pobal HP Deprivation Index for Small Areas (SA) Introduction and Reference Tables. 2016. http://trutzhaase.eu/deprivation-index/the-2016-pobal-hp-deprivation-index-for-small-areas/ Accessed 29 July, 2024.

27. Field, A. *Discovering Statistics using IBM SPSS Statistics*. 2013. 4th edn. SAGE.

28. Reddick, C. G., Enriquez, R., Harris, R.J., Sharma, B. Determinants of broadband access and affordability: An analysis of a community survey on the digital divide, *Cities*, 2020, 106. 102904.

29. Whitacre, B., Gallardo, R. and Strover, S. Broadband's contribution to economic growth in rural areas: Moving towards a causal relationship, *Telecommunications Policy*, 2014, 38(11), 1011–1023.

30. González-Betancor, S. M., López-Puig, A. J. and Cardenal, M. E. Digital inequality at home. The school as compensatory agent, *Computers & Education*, 2021, 168(104195).

31. Wolny, A. Are suburban commuters confined to private transport? A case study of a medium-sized functional urban area (FUA) in Poland, *Cities*, 2019, 92, 82–96

32. Valenzuela-Levi, N. The rich and mobility: A new look into the impacts of income inequality on household transport expenditures, *Transport Policy*, 2021, 100, 161–171.

33. St-Louis, E., Manuagh, K., van Lierop, D and El-Geneidy, A. The happy commuter: A comparison of commuter satisfaction across modes, *Transportation Research Part F: Traffic Psychology and Behaviour*, 2014. 26, pp. 160–170.

34. Archer, E. *Broadband speeds in Ireland*. https://switcher.ie/broadband/guides/broadband-speed/broadband-speeds-in-ireland/ Accessed 29 July, 2024.