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Impact of Public Transportation on European Countries' Development: a Spatial Perspective

Abstract

Sustainability is a key topic nowadays, mostly because in the last decade the pollution levels have reached an all-time high. National governments are searching for sustainable and environmentally friendly solutions to decrease the amount of pollution. This study is a cross-sectional study on 27 European countries, using data gathered in 2020. This study's main goal is to show the environmental sustainability of public transportation and its impact on country development in Europe. The methodology used in this study will consist of spatial econometrics methods with visual maps and graphs to help with a better visual representation of the phenomena presented. The empirical evidence will be confirmed by the spatial regression's results. Because the spatial diagnostic tests revealed that the spatial processes are present in terms of both spatial lag and spatial errors, the model that was used was a Spatial Autoregressive Moving Average Model (SARMA). Moreover, the environmental sustainability of public transport is also a significant factor. The expected results from which this study began – specifically, that the spatiality has a significant impact in modelling the relationship between public transportation and economic development – were confirmed.

Keywords

Spatial Econometrics | Econometric Methods | Spatial Autoregressive Moving Average Model | Spatial Autocorrelation | Transportation Economics

JEL Codes

C1, C21, R4

1. Introduction

Urbanisation has rapidly increased worldwide, resulting in increased mobility demands and environmental challenges. Public transport plays a pivotal role in achieving sustainable development goals by addressing issues such as reducing greenhouse emissions, improving air quality, enhancing accessibility, and promoting social equity.

Looking at public transport from social equity point of view, Cervero and Golub (2007) had their focus on informal transport and how it helps in some areas where public transport doesn't have enough coverage. They state that 'In many areas, informal services are the only bona fide means of mobility available to the poor. They allow car-less, disadvantaged individuals to reach jobs, buy and sell produce, and access medical care' (Cervero & Golub, 2007, p. 456).

Greenhouse emissions have rampantly increased in recent years due to various causes, and road transportation is one of them. Due to countries' development over time, most individuals tend to use personal vehicles as a way of transportation because it's convenient, but this decision has a higher impact not only on environment but also on time spent in traffic and public safety. Public transport is a more sustainable and safer alternative, aiding in reducing greenhouse emissions, traffic congestions, and not least being cost-effective. To achieve a higher attractiveness of public transport, it is necessary to implement measures to reduce personal vehicle transportation (Gärling & Schuitema, 2007).

Having in mind public transport and its sustainability, Jeon (2007) had his focus on the aspects that need to be met for public transport to be sustainable. These aspects are: public transport efficiency, impact

of the transport system on development, impact on quality of life, and impact on the environment.

To have a broader point of view in regards to public transportation, it's important to observe many aspects, not only the sustainability and cost-effectiveness. For instance, Beirão and Cabral (2007) have analysed public transport from comfort and quality perspective, their results indicate that if the overall image and comfort of public transport is improved, people would be more inclined to switch from personal vehicles to public transport.

Looking at public transport's impact on regional development, Elburz and Chubukcu (2018) have analysed the relationship using a spatial Durbin model (Anselin, 1988) to observe the effect of spatiality on the regression. Their findings were opposite from the non-spatial results in the literature: 'It can be summarized that the road transport infrastructure investments contribute the regional output indirectly in Turkey'.

The literature has a vast number of articles on the topic of the impact of public transportation on economic development using classic econometric models. The gap that this study is trying to fill is proving that spatiality has a significant impact on the relationship. The spatial econometric model used and the correct discrimination of the spatial weight matrix can lead to a new study to be added to the literature, confirming the same positive results but with an addition of key information regarding the impact of spatiality.

2. Public Transport and Development

Public transport plays a key role in regional and national development, it provides accessibility, social inclusion, mobility, a safer mode of transportation, and sustains public policies by reducing energy consumption, has a lower impact on air pollution, and reducing greenhouse emissions. Public transport is classified as one of the main elements of sustainable development; it has also been called the "lifeblood" of the city (Vauchic, 1999). Public transport can affect the development of a country through different levers, such as costs, savings, sustainability, and investments.

In terms of costs and savings, public transport is more cost-effective than personal transport taking into consideration aspects such as taxes, repairs, fuel, and time. 'Thus, each additional person traveling by public transportation saves costs to themselves plus costs to remaining automobile travelers in the range of $1,505 to $2,455 per year' (Weisbrod & Reno, 2009).

Cambridge Systematics and Economic Development Research Team (1999) have issued a report analyzing the quantitative impact of public transportation on the economy. Some of the findings regarding impact of public transportation investment state that 'For every $10 million invested, over $15 million is saved in transportation costs to both highway and transit users. These costs include operating costs, fuel costs, and congestion costs'. Another key factor that is impacted by public transportation investment is employment: 'analysis indicates that in the year following the investment 314 jobs are created for each $10 million invested in transit capital funding'.

Weisbrod and Reno (2009) name some of the areas in which public transportation benefits the economy: By switching from personal vehicles to public transport, there is a decrease in costs that lead to savings, which will be redirected into other sectors of the economy, such as goods and services; public transport policies help in diminishing traffic congestion, which has a negative impact on development and causes economic agents to lose money and contracts; and in terms of costs and savings, public transport is more cost-effective than personal transport, taking into consideration aspects such as taxes, repairing, fuel, and time.

It is no surprise that public transportation is believed to be more sustainable than private car travelling; however, economists still have to justify the pricing needed for efficient usage of resources allocated to public transportation (Horcher & Tirachini, 2021).

Even if the model's specification is different and each one of the studies in the literature sees the impact from their own perspective – using different types of data and trying to implement new techniques to better represent the hypothesis – they all get to the same conclusion, which is that public transportation has an impact on economic development.

A main point of implementing policies that would increase public transport usage would be the modernisation of existing networks. People would be more inclined to switch from personal vehicles to public transportation if a certain amount of comfort is met (Beirão & Cabral, 2007). This aspect can be improved by implementing new lines of transport,

modernising the existing vehicles, and switching to electric vehicles over gas ones, which would also benefit the environment due to lower greenhouse gas emissions.

3. Methodology

Spatial econometrics has gained significant attention in recent years, and models have been developed to aid overall understanding of influential factors from the perspective of how geographical position contributes to a region's overall behavior. A few important names in the development of spatial econometric methods and models were Huang (1984), Anselin (1988), and LeSage (1997), who attracted people's interest for the field.

This study has started from a basic econometric multiple regression model, which can be seen in Equation 1. The methodology that was used has been taken from Newbold et al. (2013) and Gujarati (2004), estimation method being Ordinary Lease Squares (OLS).

Equation 1. Multiple Regression OLS Model

$$y=\alpha+X\beta+\varepsilon$$

Because the main goal of this study is to determine how spatiality has an impact on the overall regression results, the empirical model could take one of the following forms depending on the presence of spatiality. If spatial autocorrelation is present, the model should be changed to a Spatial Autoregressive Model (SAR), presented in Equation 2 (Anselin, 1988), or a Spatial Durbin Model (LeSage, 1999). If there is a presence of spatial lag in the error term, the model used should be a Spatial Error Model (SEM) (Anselin & Bera, 1998), presented in Equation 3. Lastly, if both spatial autocorrelation and spatial dependence in the error term are present, the model would be a Spatial Autoregressive Moving Average Model (SARMA), presented in Equation 4 (Huang, 1984).

Equation 2. Spatial Autoregressive Model (SAR)

$$y=\rho W_{Y}+X\beta+\varepsilon$$

Equation 3. Spatial Error Model (SEM)

$$y=X\beta+(\mathrm{I}-\lambda W)^{-1}+\xi$$

Equation 4. Spatial Autoregressive Moving Average Model (SARMA)

$$y=(I_n-\rho W_1)^{-1}\,X\beta+(I_n-\rho W_1)^{-1}\,(I_n-\theta W_2)\varepsilon$$

Discrimination between models will be made after the spatial diagnostic test is run and we can see if we have spatial dependence in the error term or in the dependent variable, or both.

The next part of the methodology consists of spatial weight matrices and choosing the best one to fit the model and the data. Firstly, there are two major types of spatial weight matrices: contiguity based and distance based. Contiguity based matrices take into consideration the shared border between two points in space. Because United Kingdom left the EU in 2019, Ireland doesn't share a common border with no other EU country; that means we will not use the contiguity based matrix because we want all countries to have at least one neighbor.

Different types of distance based spatial weight matrices were tested in order to find the one that best fit the data. Results are shown in Table 1. The discrimination was based on Global Moran's I value (Moran, 1950), used to test for global spatial autocorrelation. The null hypothesis H0 for the Moran's I is that there is no spatial autocorrelation.

Table 1. Spatial Weight Matrix Discrimination

Weight Matrix type	Moran's I	Pseudo P-Value Moran
W1010km	0.318	0.004
W1250km	0.209	0.006
W2nearest	0.699	0.001
W4nearest	0.536	0.001
W5nearest	0.487	0.001

The best spatial weight matrix when we discriminate by Moran's I test is the one with the lowest value of the I. We also have to reject the null hypothesis. After trying different distance matrices, the best one to fit the data was the one based on 1250 km distance; any distance above 1250 km can

Table 2. Variables Description

Variable Alias	Variable Name	Description
Log GDP/Cap	Development	Economic development is the endogenous variable of the study, and it's represented by a country's logged GDP/cap value
Transport	Public Transportation	Public transportation represents the exogenous variable of the study and was calculated as total volume of km travelled by road and rail transportation by the average citizen of the country in the year of reference
Greenhouse	Sustainability	Used as a control variable for sustainability, the greenhouse variable represents the total CO2 emissions per capita
Education	Education	A proxy variable was used to represent education, namely the graduates in tertiary education by age groups per 1000 of population between the ages of 20 and 29
Attractiveness	Country Attractivity	Attractivity of the country is a dummy variable that takes the value 1 for the 5 most attractive countries in the EU in terms of investments
Log Roads	Infrastructure	As a proxy to represent a country's infrastructure, the logged value of the total km of roads was used

be neglected as the influence is not strong enough to have a significant impact.

4. Data

Data is comprised of six socio-economic variables: one dependent variable representing the economic development, an exogenous variable representing the public transport, and four other control variables. The data belonging to the 27 European Union countries, gathered for the year 2020, was extracted from the Eurostat database. Because the statistical population of the study is small, other variables were not added to avoid over-specifying the model. The variables used and the way they were calculated is presented in Table 2.

5. Findings

We start the analysis with some descriptive statistics shown in Table 3. A brief interpretation of the descriptive statistics for the transport variables shows that the values of km traveled by one citizen of the country on average deviates with approximately 3.68 km from the mean (13.13). The distribution for the transport variable is positively skewed with a value of 3.68 and the shape is platykurtic with a kurtosis value of 0.17.

Table 4 shows the correlation between variables. The main variables of the study, meaning GDP/Cap (development) and Transport (public transport), are positively correlated with a value of 0.26, revealing a weak direct relationship between them.

Continuing with standard deviation maps, comparing the exogenous and endogenous variables provides a first visual glance of the possible spatial phenomena. From Figure 1, it's difficult to see an immediate positive or negative orientation relationship between the two variables.

In terms of public transport, the spatial orientation is not visible. most of the countries have lower transport levels with some exceptions, such as Luxemburg and Malta, which are positive outliers. This phenomenon could be present because in March 2020, Luxembourg adopted free public transport, encouraging citizens to travel more by public transport. Malta on the other hand adopted free public transportation only in 2022 for the majority of the population, but the deviation from the mean amount of transportation across the rest of the EU could be because of the senior population over age 75, who has benefited from free public transportation since January 2020.

In th GDP capita standard deviation map, we can clearly observe some clusters in Central, Eastern, and Northern Europe. Central European and Northern European countries have higher values of GDP capita compared to Eastern European countries, with Luxembourg being an outlier.

Table 3. Descriptive Statistics

Variables	GDP/Cap	Transport	Sustainability	Education	Attractiveness	Log Roads
Mean	4.41	13.13	7.92	57.24	0.18	1.97
Median	4.37	12.9	7.3	53.6	0	1.98
Standard Error	0.05	0.71	0.51	3.41	0.08	0.13
Standard Deviation	0.26	3.68	2.64	17.7	0.39	0.67
Skewness	0.41	0.34	1.62	0.56	1.72	−0.61
Kurtosis	−0.33	0.17	4.17	0.96	1.02	0.24
N	27	27	27	27	27	27

Table 4. Correlogram

Variables	GDP/Cap	Transport	Sustainability	Education	Attractiveness	Log Roads
GDP/Cap	1	0.265306	0.678325	0.050464	0.345262	−0.11932
Transport	0.265306	1	0.215899	−0.44597	0.054979	−0.75423
Sustainability	0.678325	0.215899	1	−0.17053	0.246438	−0.23339
Education	0.050464	−0.44597	−0.17053	1	−0.1022	0.437435
Attractiveness	0.345262	0.054979	0.246438	−0.1022	1	0.005346
Log Roads	−0.11932	−0.75423	−0.23339	0.437435	0.005346	1

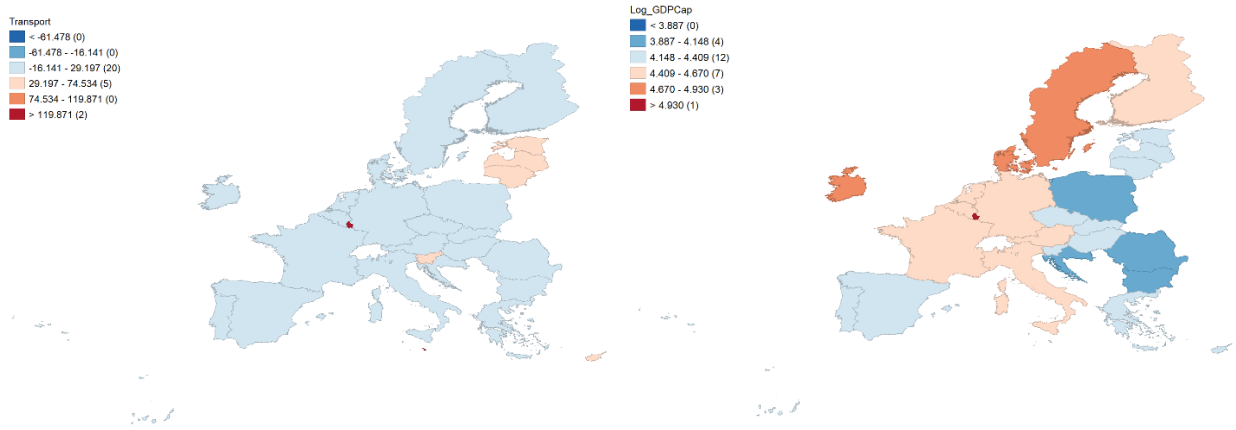


Figure 1. Standard Deviation Map Display for Public Transport and Development

To calculate the spatial autocorrelation, Moran's I test was used, where the null hypothesis for the test is that the data is randomly dispersed, meaning there is no autocorrelation. Figure 3 shows a value of 0.209 of univariate local Moran's I for development. The null hypothesis was rejected with a pseudo p-value of 0.006 (see Appendix 1). Moran's I positive sign shows the presence of the spatial process called diffusion, meaning that countries are spatially positioned near neighbors with similar behavior in terms of development: high GDP per capita countries are positioned near high GDP per capita neighbors, and the same goes for low GDP per capita countries.

Bivariate spatial autocorrelations between public transport and development can be found in Figure 3. Moran's I value is negative, indicating the presence of polarisation. The null hypothesis was rejected for a pseudo p-value lower than 0.05 (see Appendix 2), revealing that a country's neighbors have opposite

behavior. For instance countries with high GDP per capita values are spatially autocorrelated with countries with low values of public transport. Maps presented below show the links created For the public transport and development, we have prominently Low-High and Low-Low links, meaning that countries with low values in terms of public transport are spatially correlated with high GDP per capita countries (Low-High).

Testing the multiple OLS regressions seen in Table 4 indicates right from the start that there are no multicollinearity problems for either relationship, as the multicollinearity value is below the maximum permitted value of 30. Residual diagnosis shows that residuals are normally distributed with a Jarque–Bera value of 1.34, failing to reject the null hypothesis that the residuals are normally distributed. The problem of the OLS model in this case is that the residuals are heteroskedastic due to spatial dependencies. The Breusch–Pagan test value of 8.23 indicates that we fail to reject the null hypothesis (p-value > 0.05), resulting in the assumption that an OLS model is not appropriate for this dataset.

The diagnostic test for spatial dependencies seen in Table 5 below indicates significant spatial dependencies with both spatial lag and errors. Therefore the OLS regression is rejected, indicating that a SARMA model will be best fitted to capture both the spatial lag and errors.

The weight matrix used in the SARMA model to estimate regression's parameters was a distance-based matrix for 1250 km distance. Queen or Rook contiguity matrices are not representative since they both calculate the neighbors based on shared borders. Because United Kingdom left the European Union in 2019, Ireland has become isolated from any other European Union Country in terms of neighboring borders.

The regression results seen in Table 6 indicate a significant positive relationship between public transport and development. Increasing public transport by one trip per citizen can generate an increase of 0.87% in GDP per capita ceteris paribus. Moreover, a country's development is explained in proportion of 58% by public transport, sustainability,

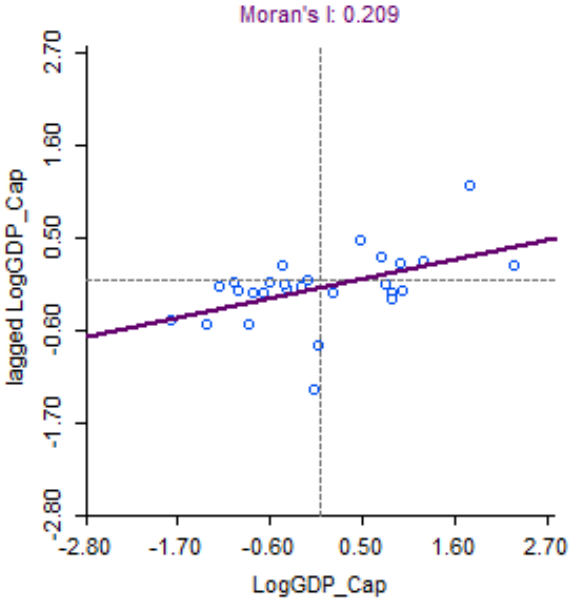


Figure 2. Local Spatial Autocorrelation for Development

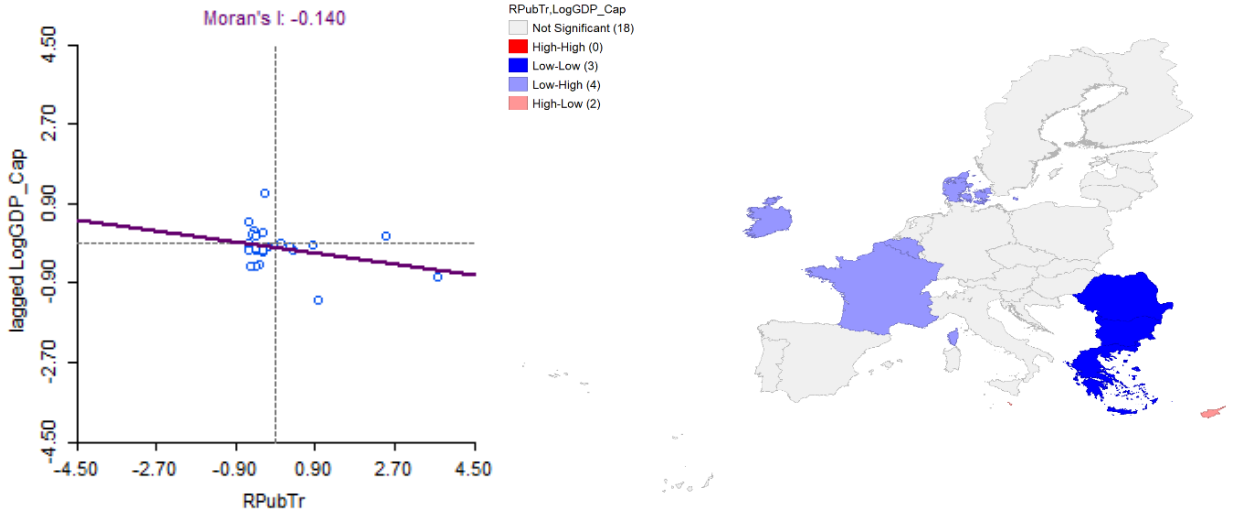


Figure 3. Bivariate Spatial Autocorrelation for Public Transport and Development

Table 4. Multiple OLS Regression Between Public Transport and Development

Variables	Log GDP/Cap
Transport	0.0731**
	(2.39)
C	7.6408***
	(11.58)
Greenhouse	0.1220***
	(3.4)
Education	0.116*
	(2.03)
Attractiveness	0.2936
	(1.27)
Log Roads	0.1747*
	(1.93)
Adjusted R-Squared	0.43
F-Statistic	4.98***
Multicollinearity	17.99
N	27

*** - Significant for 99% confidence level, ** - Significant for 95% confidence level, * - Significant for 90% confidence level

Table 5. Diagnostics for Spatial Dependence

Diagnostics for Spatial Dependence	Log GDP/Cap
Moran's I (errors)	1.3554
Prob	(0.17)
Lagrange Multiplier (lag)	1.5050
Prob	(0.21)
Robust LM (lag)	6.3663
Prob	(0.11)
Lagrange Multiplier (errors)	0.1421
Prob	(0.71)
Robust LM (errors)	5.0035
Prob	(0.02)
Lagrange Multiplier (SARMA)	6.5084
Prob	(0.03)

Table 6. SARMA Regression Model Between Public Transport and Development

Variables	Log GDP/Cap
Transport	0.0087***
	(3.21)
C	-4.5844
	(-1.12)
Greenhouse	0.0925***
	(2.85)
Attractiveness	0.1129
	(0.67)
Education	0.0011
	(0.17)
Log Roads	0.1809**
	(2.21)
Weighted Dependent Var.	1.2699***
	(2.73)
Lambda	-1.0000
	(-0.75)
Pseudo R-Squared	0.58
N	27

*** - Significant for 99% confidence level, ** - Significant for 95% confidence level, * - Significant for 90% confidence level

attractiveness, and infrastructure. In addition, bearing in mind that the environmental sustainability matter was previously discussed, the impact of environmental sustainability was also strongly significant and positive on country development. Policy implications indicate that greenhouse gas emissions are linked to the high rate of economic activity.

6. Conclusion

This study's main goal was to determine whether public transport has a significant positive impact on a country's development, as many studies in the literature have previously confirmed; to see if there are spatial dependencies; and if the presence of spatiality adds relevant information about the phenomena.

Public transport has been confirmed to have a significant positive impact on a country's development, supporting the economic theory this study has followed. Spatiality is present and has a positive impact. The spatial weight matrix of the dependent variable shows that the spatial autocorrelation had a positive and significant coefficient. Excluding spatiality from the analysis would have led to an inconsistency in overall significance of the coefficients due to spatial dependencies.

The gap in the literature that this study is filling consists in the method of modelling the relationship beyond a two-dimensional space that only looks at things from a cross-sectional point of view without digging deeper into the impact geographical position. This study has revealed that spatiality should be taken into consideration when analyzing regions, countries, and other points in a defined geographical space because neighbors have an impact on each other.

The policy implication of the study consists in the polarisation phenomena that was present, developed countries tending to absorb more transport infrastructure investments than their neighbors. In order to stop this attitude, national governments and competent institutions must take actions in developing public transport networking. The EU gives out funds for modernization of public transportation, specifically for purchasing electric vehicles for transport. This aid would help in decreasing the discrepancies between EU countries in terms of public transport and would also have a positive impact on the countries' development.

The limitations this study has are that the year 2020 was an atypical year due to the COVID-19 pandemic, but the assumption was that there was an overall decrease in all sectors of activity in 2020, and the direct relationship between the variables would be that in a crisis scenario, they would both decrease. A suggestion for future studies would be using a Spatial Durbin panel model to try to capture the dynamics of public transportation, including the pandemic, in the analysis in order to see if it had any impact on the relationship.

References

Anselin, L. (1988). *Spatial Econometrics: Methods and Models*. Dordrecht: Kluwer Academic Publishers. https://doi.org/10.1007/978-94-015-7799-1

Anselin, L., & Bera, A.K. (1998). Spatial Dependence in Linear Regression Models with an Introduction to Spatial Econometrics. *Statistics: Textbooks and Monographs*, 155, 237-289. http://www.econ.uiuc.edu/~hrtdmrt2/Teaching/SE_2016_19/References/Spatial_Dependence_in_Linear_Regression_Models_With_an_Introduction_to_Spatial_Econometrics_281_29.pdf

Beirão, G., & Cabral, J.A.S. (2007). Understanding attitudes towards public transport and private car: A qualitative study. *Transport Policy*, 14(6), 478-489. https://doi.org/10.1016/j.tranpol.2007.04.009

Cambridge Systematics, Inc. and Economic Development Research Group (1999). *Public Transportation and the Nation's Economy. A Quantitative Analysis of Public Transportation's Economic Impact*. Washington: American Public Transit Association. https://www.kcata.org/documents/uploads/T_PublicTransportationNationsEconomy.pdf

Cervero, R., & Glub, A. (2007). Informal Transport: A global perspective. *Transport Policy*, 14(6), 445-457. https://doi.org/10.1016/j.tranpol.2007.04.011

Elburz, Z., & Cubukcu, K.M. (2018). Public Infrastructure and Regional Growth Relationship from a Spatial Perspective with a Time-Varying Spatial Weight Matrix. *Proceedings 12th World Congress of the RSAI*, 58-64. https://www.regionalscience.org/images/PDF/Proceedings_RSAICongress2018.pdf

Eurostat. *Eurostat Data* [Data Set.] https://ec.europa.eu/eurostat/web/main/data/database.

Gärling, T., & Schuitema, G. (2007). Travel demand management targeting reduced private car use: effectiveness, public acceptability and political feasibility. *Journal of Social Issues*, 63 (1), 139–153. https://doi.org/10.1111/j.1540-4560.2007.00500.x

Gujarati, D.N. (2004). *Basic Econometrics Fourth Edition*. New York: United States Military Academy. https://zalamsyah.staff.unja.ac.id/wp-content/uploads/sites/286/2019/11/7-Basic-Econometrics-4th-Ed.-Gujarati.pdf.

Horcher, D., & Tirachini, A. (2021). A review of public transport economics. *Economics of Transportation*, 25(1). https://doi.org/10.1016/j.ecotra.2021.100196

Huang, J.S. (1984). THE AUTOREGRESSIVE MOVING AVERAGE MODEL FOR SPATIAL ANALYSIS. *Australian Journal of Statistics*, 26(2), 169-178. https://doi.org/10.1111/j.1467-842X.1984.tb01231.x

Jeon, C.M. (2007). *Incorporating sustainability into transportation planning and decision making: Definitions, performance measures, and evaluation*. Atlanta: Georgia Institute of Technology. https://doi.org/10.3141/2174-09

LeSage, J. P. (1997). Bayesian Estimation of Spatial Autoregressive Models. *International Regional Science Review*, 20(1–2), 113–129. https://doi.org/10.1177/016001769702000107

LeSage, J.P. (1999). Spatial Econometrics. *The Web Book of Regional Science*. Morgantown: Regional Research Institute, West Virginia University. https://rri.wvu.edu/web-book

Moran, P.A.P. (1950). Notes on Continuous Stochastic Phenomena. *Biometrika*, 37(1),17-23. https://doi.org/10.1093/biomet/37.1-2.17

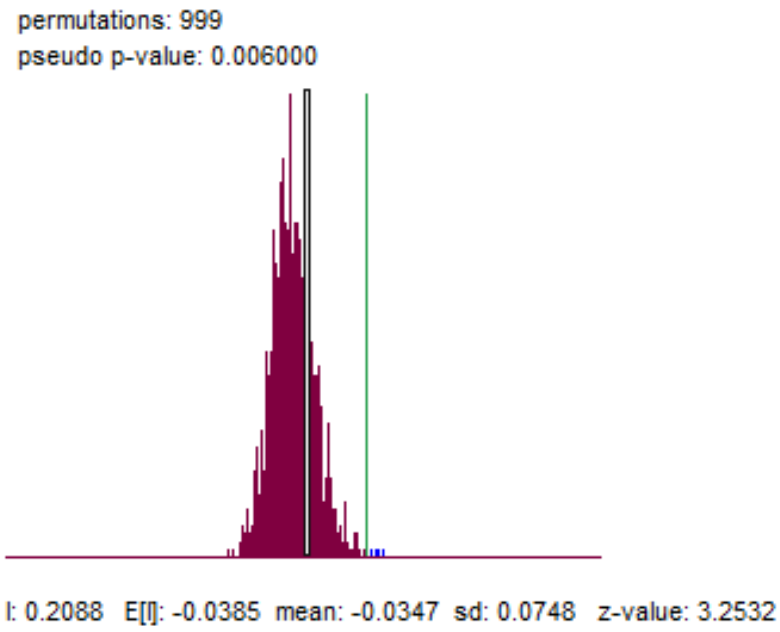
Newbold, P., Carlson, W.L., & Thorne, B.M. (2013). *Statistics for Business and Economics*, London: Pearson Education Limited. https://handoutset.com/wp-content/uploads/2022/07/Statistics-for-business-and-economics-Paul-Newbold-William-Lee-Carlson-etc..pdf

Vauchic, V.R. (1999). *Transportation for livable cities*, New Brunswick: Centre for Urban Policy Research. https://doi.org/10.1023/A:1017551925033

Weisbrod, G., & Reno, A. (2009). *Economic Impact of Public Transport Development*, Washington: American Public Transportation Association. https://onlinepubs.trb.org/onlinepubs/tcrp/docs/TCRPJ-11Task7-FR.pdf

APPENDIX

Appendix 1. Moran's I Pseudo P-Value for Development



Appendix 2. Bivariate Moran's I Pseudo P-Value for Public Transport and Development