The Relationship between Land Use and Bicycles: A Case Study in the Manhattan Area of New York City, USA

Jiawei Shi *

Chang'an Dublin international college, Chang'an university, Xi'an, China

* Corresponding author: jbrewer60376@student.napavalley.edu

Abstract. With rapid, sprawling cities, travel is becoming increasingly car-orientated, which can create several problems. Smart growth strategies are seen as an effective way of dealing with this problem, centered on the interrelationship between transportation and land use. However, this relationship is still being determined. This paper uses various regression methods based on bicycle trip data from the Manhattan area of New York City, and explores the relationship between the number of restaurants, amenity facilities, income, rent, population, and the number of trips. The results show that the account of shopping facilities, rent, and population performs better and has a more significant positive correlation with the number of bicycle trips due to its better R-squared value and smaller possible multicollinearity. Triggered discussion on the impact of land use mix on travel selection. It illustrates land use mixing significantly reduces car trips, increases the use of surrounding transport facilities, and is politically feasible.

Keywords: Bicycles, Land Use, Manhattan Area, New York.

1. Introduction

As urbanization accelerates globally, it leads to rapid, uncontrolled urban sprawl. In Europe and North America, there are growing concerns about the development of urban form, particularly the dispersal of urban land use in the form of urban sprawl, which can have unintended consequences. In the United States, some environmental organizations such as the Sierra Club have argued that in communities across the United States, urban sprawl has, to some extent, depleted local resources and contributed to the loss of open space [1]. The sudden increase in automobile use and personal travel has also led to a tendency for much of the current land use policy to favour automobile trip-oriented planning, which often means a gradual shift in development patterns from relatively compact and supportive of public transport development to dispersed and dependent on private vehicle development, resulting in the existing transport network becoming increasingly unfavourable to pedestrians and public transport [2]. These concerns and issues have fueled the momentum of the smart growth movement. Smart growth has been part of the American planning vocabulary and has gained increasing support over the decade [3]. In general, smart growth is viewed as a strategy to stop urban sprawl and create better communities since it emphasizes how transportation and land use are interconnected. The finest examples of how smart growth ideas are used, according to the American Planning Association [4], are site redevelopment and short, transit-accessible, pedestrian-oriented, multifunctional building patterns. Use exemplifies how smart growth ideas are put into practice. The interrelationship between the two is at the heart of the U.S.'s use of smart growth strategies to combat urban sprawl. Intuitively, it is commonly acknowledged that land use affects travel demand and patterns, and that there is a reciprocal link between land use and transportation. Changes in accessibility levels reflect how transportation impacts land use, which in turn influences the preferred method of transportation [5]. Smart growth strategies look to apply this two-way relationship, such as increasing the mix of land use types to reduce car-orientated trips and promote walking, cycling and public transport. By improving the transport infrastructure, the transport network will increase accessibility and thus reduce the cost of travel. At the same time, increased connectivity will diversify the choice of transport modes.

Therefore, determining the exact relationship between transport and land use is a critical factor in assessing the effectiveness of smart growth strategies. The purpose of this paper is to explore the relationship between various socioeconomic variables and the number of bicycle trips in New York City, USA, using bicycle trips as the object of study, and thus to explain to some extent the relationship between land use and transportation.

2. Background

New York epitomises the development of smart growth strategies. As early as the mid-20th century, architect Robert Moses built the New York Expressway System on the principle that "traffic creates the city, and the city exists for the sake of traffic". However, his over-emphasis on vehicular speed and smooth traffic flow prompted the construction of more and more motorways, ignoring the feelings of pedestrians and the value of public transport. This led to criticism and opposition from Jane Jacobs, known as the "mother of humanistic planning". Jacobs had always advocated pedestrian-led transport and the principle that land should be mixed-use and streets should be made more accessible to pedestrians. The conflict between the two sides was further fueled by the construction of the Lower Manhattan Expressway in 1968 [6]. Jacobs organized a grassroots effort to protest heavily against the matter and was arrested for "inciting the crowd" at a hearing on the project in 1968. Eventually, under public pressure, the plan was officially canceled in 1971, indirectly contributing to the subsequent construction and development of the SOHO neighbourhood in Lower Manhattan, which has been described as a classic success story of downtown regeneration. Inspired by Jacobs, The New York City Department of Transportation recruited the Danish architect Jan Gehl in 2007–2008 to redesign the city's streets and incorporate ideas that would enhance the quality of life for bikes and pedestrians. For example, in April and November 2008, he planned "Copenhagen" style bike lanes on Eighth Avenue in Manhattan. This plan doubled bicycle traffic in New York in only two years [7].

In summary, this paper explores the Manhattan area of New York, an active bicycle travelling area (Figure 1).

Figure 1. New York City Manhattan

3. Methodology

3.1. Data

This paper primarily uses data on trips made by public bicycles leased by users in New York City during June 2018, focusing on the terminating station for each bicycle trip. Other relevant data includes socioeconomic data for New York City during the same period, such as the number of restaurants, shopping facilities, income, population, and rents.

3.2. Methods

The whole idea of the inquiry is divided into three steps:

(1) Determine the relationship between a single variable, such as the number of restaurants and bicycle trips.

(2) Explore the localized relationship between a single variable, such as the number of amenities and bicycle trips for a specific block group.

(3) Obtain the relationship between multiple socioeconomic variables and the number of bicycle trips.

The above analysis and visualization process was implemented through ArcGIS Pro. Determining whether and how a linear relationship exists between two continuous variables can be achieved by calculating Pearson's correlation coefficient, i.e., by taking the value of r. However, Pearson's correlation coefficient is not available in ArcGIS Pro. Nevertheless, in simple univariate regression, there is a direct relationship between the square of the Pearson correlation coefficient and R-squared values, both of which have the same significance, so Ordinary Least Squares (OLS) regression can be used to determine if the number of trips is significantly correlated with the food and beverage facilities.

Local bivariate relationships in the ArcGIS analysis model can be used when exploring localized relationships. Once the local model has been analyzed, it is possible to look at the local relationships and R-squared values in any block group, again showing the interrelationship between the two variables. The advantage of the local model is the strength of predictability by the level of local entropy. Entropy is a measure of randomness or disorder within a system in thermodynamics. In information theory, entropy quantifies uncertainty or impurity in a data set. In local binary relations, entropy is used to understand the degree of randomness or uncertainty between two variables in a defined local context. High entropy indicates a high degree of disorder in the relationship between two variables. In contrast, low entropy indicates a more predictable relationship between the two. For example, the lower the local entropy in this problem, the more predictable the shopping amenity is for the trip.

When performing OLS regression, a layer of standardized residuals for each block should also be generated. The residuals in OLS represent the difference between the actual observations and the model predictions, and the residuals are standardized in order to keep them on the same scale for direct comparison. In other words, the standardized residual is a measure of the strength of the difference between the observed and expected results. It is expressed in units of standard deviation. Based on the standardized residuals, a global Moran's analysis can then be performed to detect spatial non-stationarity and determine whether a spatial statistical model like GWR or SAR is required. These further spatial analyses help determine the relationship between mixed land use types and travel.

4. Results

Table 1 presents the results of a univariate OLS regression of the relationship between dining facilities and the number of bicycle trips. The first observed point is that the standard deviation is only 0.19, which indicates that the model estimates are highly accurate and credible. The t-statistic, p-value, and robust p-value all reflect the significance of the parameter. The t-value in the table below has an absolute value of 18.96, which is a relatively large value, proving that the parameter is more significant. P-value and robust p-value have an asterisk * in the upper right corner of the value, proving that the value is less than the established significance level of 0.01, which is enormously significant. The most important thing to focus on is the R-squared value in the resultant diagnostic (Table 2), which is 0.42, possibly indicating a strong positive correlation between dining facilities and the number of trips. The histogram of standardized residuals for both variables reflects the accuracy of the OLS model (Figure 2). It proves the reliability of the results.

Table 1. Summary of OLS Results

Variable	Coefficienta	StdError	t-Statistic	Probabilityb	Robust_SE	Robust_t	Robust_Prb
Intercept	-3.107550	35.758718	-0.086903	0.930768	35.599235	-0.087293	0.930459
DINNING	3.608827	0.190309	18.962973	0.000000*	0.306107	11.789412	0.000000*

Notes: * means an asterisk next to a number indicates a statistically significant p-value (p<0.01).

Table 2. OLS Diagnostics

Parameters	Values	Parameters	Values
Input Features	NYC_Data	Dependent Variable	COUNT
Number of Observation	505	Akaike's Information Criterion (AICc)d	7659.493003
Multiple R-Squaredd	0.416875	Adjusted R-Squaredd	0.415716

Notes: d means R-Squared; AICc: measures of model performance.

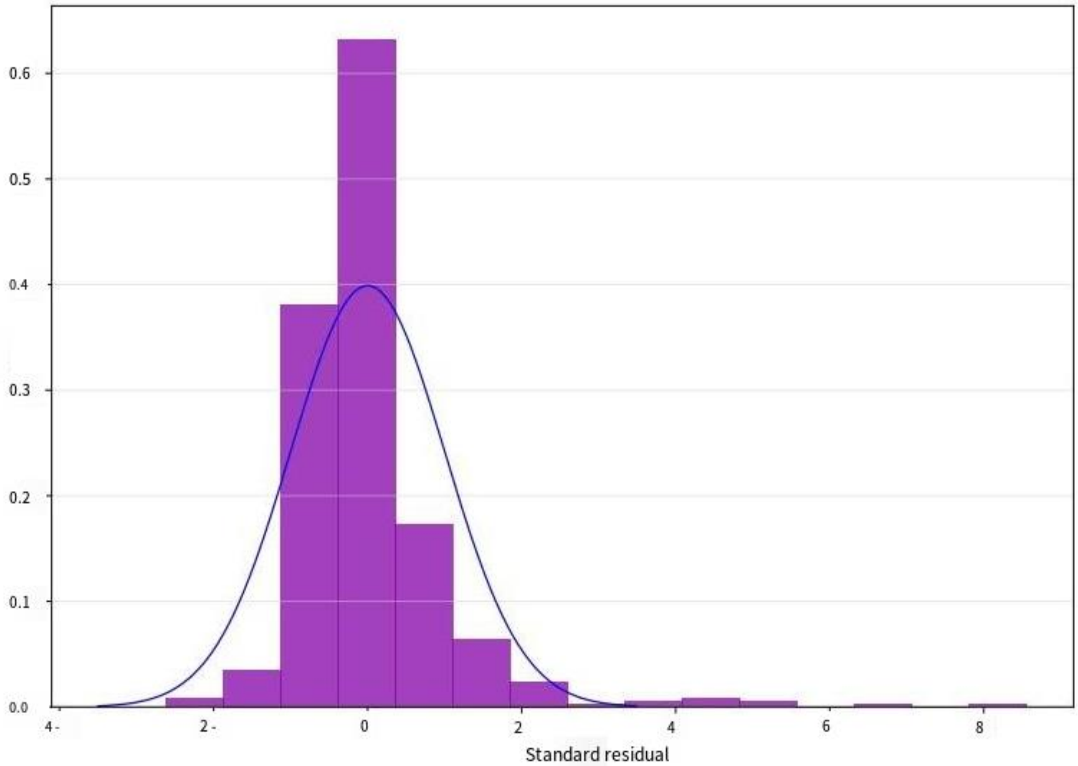

Figure 2. Histogram of Standardized Residuals (The histogram of standardized residuals would match the normal curve, demonstrating the high accuracy of the model.)

To do a reverse-verification of the OLS analysis' dependability, Pearson's correlation coefficient can be computed. With an R-squared of 0.64, the Pearson's correlation coefficient was determined. The outcome indicates that there is a substantial positive link between the two, and this association is direct.

After the local binary analysis (Figure 3), when clicking on any block, a pop-up window showing its R-squared and localized relationship will be displayed. For example, block 328 (Figure 4) is a block where the number of shopping facilities has a strong positive correlation with the number of bicycle trips. Its P-value and R-squared values perform relatively well, at 0.005 and 0.54, respectively. Entropy is the most exciting point, as shown in Table 3, with an entropy value of only about 1.20, proving that the number of shopping amenities in this neighbourhood strongly predicts the number of trips. Indeed, low entropy is equally present in neighborhoods where the dichotomy is less significant, suggesting that solid predictability exists in all neighborhoods.

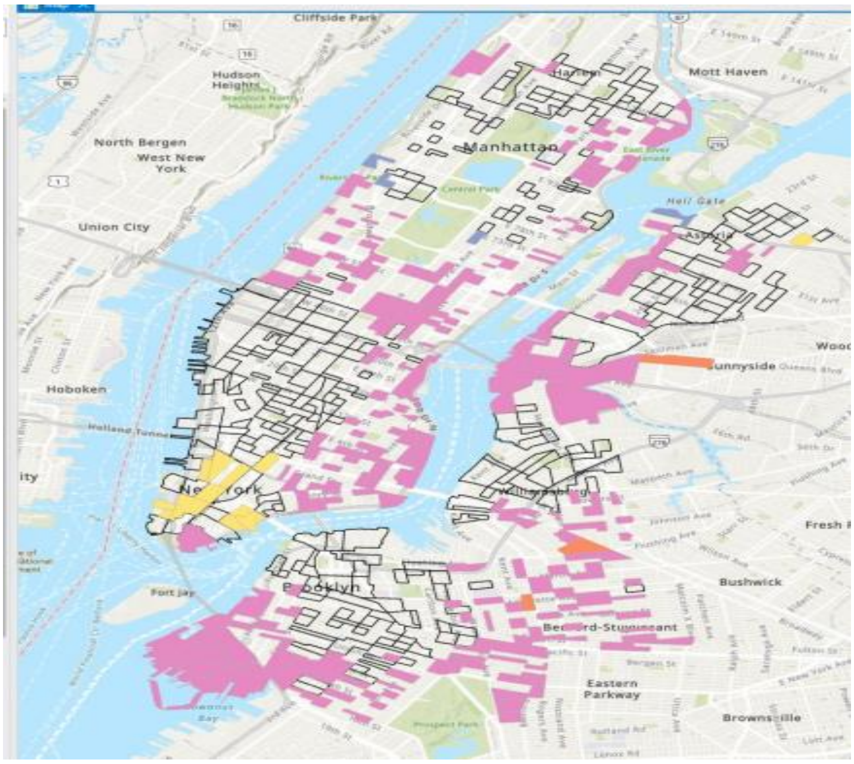

Figure 3. Local Bivariate Relationships (Colors indicate correlations. Pink, orange, yellow, and white indicate positive linear correlations, concave functional relationships, undefinable complex relationships, and no significant correlations, respectively)

Table 3. Local Bivariate Relationships Results

Entropy	P-values	Coefficient (Linear)	R-squared (Linear)
1.196801	0.005	0.672253	0.542297

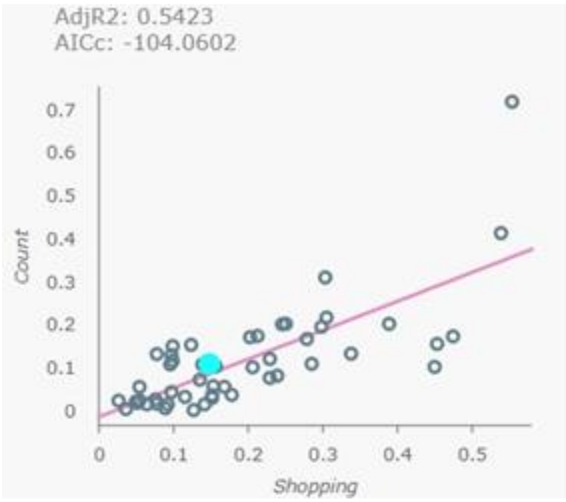

Figure 4. Localization Relationship

After performing multivariate OLS regression for restaurant facilities, shopping facilities, rent, population, and income, the first thing that should be focused on is the VIF value (Table 4). It is generally believed that independent variables with VIF values greater than 7.5 are highly correlated with the other independent variables and may have multicollinearity problems, making the regression coefficients inaccurately estimated and making the results unstable and challenging to interpret. Therefore, the effect of restaurant facilities should be excluded and focus on the remaining four variables. P-value and robust p-value indicate that the relationship between income and number of trips is insignificant, while the other three variables are relatively significant. Furthermore, the R-squared value of 0.49 indicates that the combination of these independent variables can better explain the variation in the dependent variable (Table 4). After all the above explorations, it can be stated to some extent that the mixed use of land is correlated with bicycle travelling and may promote smart growth strategies.

Table 4. Multi-OLS Results

Variable	Coefficienta	StdError	t-Statistic	Probabilityb	Robust_SE	Robust_t	Robust_Prb	VIFc
DINNING	1.991051	0.500640	3.977012	0.000088*	0.744485	2.674402	0.000053*	7.855766
SHOPPING	1.047904	0.423204	2.476122	0.013601*	0.529996	1.977189	0.048564*	7.398431
POPULATION	0.118220	0.020241	5.840532	0.000000*	0.049042	2.410573	0.016275*	1.006642
RENT	0.117282	0.038971	3.009476	0.002759*	0.045636	2.569944	0.010452*	2.713079
INCOME	0.000522	0.000523	0.998005	0.318749	0.000608	0.858777	0.390863	2.493143

5. Discussion

Population, number of shopping facilities, and rent can all indicate the degree of land use mix. The positive correlation between the three and the number of trips in the above results suggests a link between the land use mix and travel mode choice. According to research [8], the relationship between land use and transportation may be understood in terms of how a region's mix of land uses, residential and employment density, and travel patterns affect each other. In order to support smart growth policies, this article only addresses how reduced automobile trips result from mixed land use.

Previous research has shown that mixed land uses have multiple transportation-related benefits, including reductions in vehicle trip generation rates and vehicle travel hours. For example, mixed land use reduced vehicle trip generation rates by 25% in Greater Denver. Another study showed that the average daily travel time in communities with mixed land use was 2.3 to 2.8 hours, lower than the 3.4 hours in auto-oriented communities [2]. Mixed land uses near employment sites, such as introducing other services such as banks, restaurants, and shops near office buildings, have also been found to reduce car trips. It has been found that a 100,000 square foot office block with 25,000 square feet of general office space, 25,000 square feet of research and development space, 40,000 square feet of multi-family apartments and 10,000 square feet of specialized retail space reduces daily traffic by 18.7% when compared to a single-use design [9].

An increase in the utilization of neighboring transportation facilities is correlated with higher levels of mixed land use. According to one of the studies, mixed-use construction increased the utilization of neighboring transportation systems by 30% in center cities and 9% in suburban regions. Particularly, mixed-use regions outperformed those with lower levels of land use mix in that driving alone declined by 4.4% and traffic rose by 3.5% [10].

The distance between complementing land uses directly affects travel decisions, contrary to other research' findings that land use mix is ineffective for reducing automobile journeys. For instance, locals may decide to walk rather than drive if they can go to the corner store to buy groceries or pick a restaurant within a 5 to 10-minute walk (about 1/ 4 mile). Driving there is more likely if the same restaurant is more than a mile away and can be reached in 20 minutes [11]. This school of thought contends that rather than just mixing uses, there has to be more pedestrian connection between adjacent land uses to encourage non-motorized transportation.

Last but not least, in terms of political viability, mixed land use is a more viable and less resistant method of enhancing access to opportunities and services than densification (intensive development), which can be marketed as a gentler method of enhancing access to opportunities and services when local opposition to increased residential density is frequently insurmountable [2].

6. Conclusion

In this paper, the relationship between the number of restaurants, shopping facilities, income, rent, and population and the number of trips was obtained through univariate OLS regression, local binary relationships, and multivariate OLS regression in the context of a smart growth strategy, using data on bicycle trips in the Manhattan area of New York City. The results show that in the multivariate regression, the number of shopping facilities, population and rent have a more significant positive relationship with the number of trips when the VIF and R-square values are considered together. To a certain extent, land use mixing can influence the choice of travelling mode. This leads to a discussion of the effect of mixed land use on reducing car trips. The paper presents views and evidence on both sides of the argument that mixed land use can reduce car trips and the argument that it is not a critical factor influencing travel choices. Mixed-use is more politically viable than single densification and could be vital for smart growth.

References

[1] Handy, S. Smart growth and the transportation-land use connection: What does the research tell us? International regional science review, 2005, 28 (2), 146 - 167.

[2] Frank, L. D. Land use and transportation interaction: implications on public health and quality of life. Journal of Planning Education and Research, 2000, 20 (1), 6 - 22.

[3] Ye, L., Mandpe, S., & Meyer, P. B. What is “smart growth?”—Really? Journal of Planning Literature, 2005, 19 (3), 301 - 315.

[4] American Planning Association. Policy guide on smart growth. 2002. Retrieved September 23, 2023, from http://www.planning.org/policyguides/pdf/SmartGrowth.pdf.

[5] Iacono, M., Levinson, D., & El-Geneidy, A. Models of transportation and land use change: A guide to the territory. Journal of Planning Literature, 2008, 22 (4), 323 - 340.

[6] Flint, A. Wrestling with Moses: How Jane Jacobs took on New York's master builder and transformed the American city, 2009, Random House.

[7] New York City Department of Transportation. New York City DOT Releases World Class Streets Report, Calling for Enhanced Public and Pedestrian Space. 2023.

[8] Cervero, R. Mixed land-uses and commuting: Evidence from the American Housing Survey. Transportation Research Part A: Policy and Practice, 1996, 30 (5), 361 - 377.

[9] Ewing, R., & Cervero, R. Travel and the built environment: a synthesis. Transportation research record, 2001, 1780 (1), 87 - 114.

[10] Ewing, R., & Dumbaugh, E. The built environment and traffic safety: a review of empirical evidence. Journal of Planning Literature, 2009, 23 (4), 347 - 367.

[11] Knudsen, B. B., & Clark, T. N. Walk and be moved: How walking builds social movements. Urban Affairs Review, 2013, 49 (5), 627 - 651.